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GEOLOGICAL SURVEY.

AND WALES.

THE WATER SUPPLY

OF

BUCKINGHAMSHIRE

AND OF

HERTFORDSHIRE

FROM UNDERGROUND SOURCES.

BY

W. WHITAKER, B.A., F.R.S.

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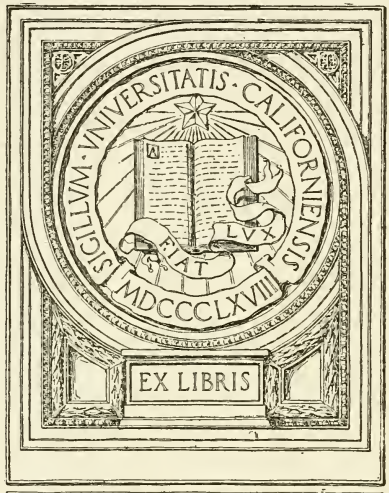
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MEMOIRS OF THE GEOLOGICAL SURVEY.

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Notes on Sources of Temporary Water Supply in the South of England and Neighbouring Parts of the Continent, 1914. Price 2d.

PREFACE.

In this memoir Mr. Whitaker has dealt with the water-supply of the contiguous counties of Buckinghamshire and Hertfordshire and the volume in consequence is larger than most of the previous memoirs of this series. The counties have all essential features in common and their water-supplies are of similar types. All available published records have been included and much new information collected from a great variety of sources. Many engineers, well-sinkers, and borers have given valuable assistance, and the author is indebted to many owners, tenants, estate agents, companies, and water authorities for important details. Acknowledgment is made, wherever possible, in the text, but he wishes especially to express his indebtedness to Mr. J. M. Wood, of the Metropolitan Water Board, and to the late Mr. W. W. Fisher, County Analyst for Buckinghamshire, for much information, as well as to Dr. Boycott, and to Mr. C. Oldham for looking through proofs.

The name of the late John Hopkinson is indissolubly associated with the study of Hertfordshire underground waters, rainfall, percolation, etc., and Mr. Whitaker was fortunate in obtaining his co-operation and sagacious advice in the preparation of the manuscript of the Memoir.

JOHN S. FLETT,

Director.

Geological Survey Office,
28, Jermyn Street,
London, S.W. 1.

8th January, 1921.

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INTRODUCTORY.

It will be useful in the first place to get some idea of what is meant by Buckinghamshire, and Hertfordshire, and, having myself taken some trouble in getting out various particulars as to these counties for my own use, they may be given for the benefit of others.

BOUNDARIES.

An English county, as a rule, is far from being a great natural division, its boundary being often of a thoroughly artificial character, and any relation thereof to natural features being very generally wanting. Of the 13 counties already treated of in these Water Memoirs 7 have a sea-border, and 5 of these have also in part a tidal river as a border, whilst another has in part a large tidal river ; but in the present case we are dealing with purely inland counties, one certainly coming down to a large river at one border, and the other being partly bounded by a smaller river.

One great physical feature, the Chalk-escarpment, runs through both counties, but has practically nothing to do with their boundaries.

Buckinghamshire.

The southern boundary of this county is a natural one, following the Thames throughout, except for two very small shiftings into the bordering alluvial meadows.

The eastern boundary, starting from the Thames in the parish of Wyrardisbury, runs up the tributary Colne to the northern boundary of the parish of Denham. Then it runs very irregularly right across the hills and valleys of the Chalk to Drayton Beauchamp where it passes over the lower ground of the Gault, to the north ; but soon returns to the Chalk at Marsworth, whence it runs most irregularly over the hills to Dagnall. North-westward from there it follows the little stream forming the head-water of the Ouzel, along which river it goes on to Linslade, whence it takes an irregular cross-country course for many miles, to the Ouse, at Newton Blossomville, following the river only for about three miles northward.

The northern boundary runs thence irregularly across country to the Tove.

The western boundary runs along the Tove from west of Hanslope to its junction with the Ouse, by Wolverton. Then it follows up the Ouse to Thornton, leaves that river northward and is of a purely artificial character until reaching the higher waters of the Ouse at Biddlesden. It follows that stream in its downward course, to Water Stratford, and then again takes to an irregular course southward until it reaches a branch of the Ray near Marsh Gibbon. Soon leaving that stream it again takes to an irregular cross-country course southward to the River Thame, by Worminghall. It runs up that stream, with one slight deviation, to Thame, whence it takes to the tributary Ford Brook up to Aston Sandford ; and then goes irregularly across country to the Cottle Brook near Bledlow, and then irregularly across the Chalk hills and valleys to the Thames in the parish of Fawley.

(845.) Wt. 37456—11. 500. 1/21. J. T. & S., Ltd. G. 14.

Hertfordshire

Starting from the west the southern boundary of this county runs up to the Colne, for over two miles, nearly to Rickmansworth, and then goes eastward across country, to the Lea at Waltham Cross, with a very irregular set of loops in the middle part, around Barnet, and throughout with no constant relation to hill or valley.

The eastern boundary runs northward up the Lea to the junction with the Stort, and then up that tributary to the southern end of Bishop's Stortford, when it turns eastward for a short distance, returning to the river just above that town, for about a mile, and then westward for little more than two miles and again takes a northerly direction across the clay-covered Chalk, in a fairly even course (as compared with the wandering courses so general in both counties) to a point about three miles east of Royston.

The northern boundary runs along the Icknield Way westward for several miles, except for a small excursion northward round the town of Royston, which was formerly divided, by that road, between the counties of Cambridgeshire and Hertfordshire, an awkward case of one side of a main street being in one county and the other side in another county, which was got rid of not very many years ago. Then the boundary turns northward to some three miles beyond Ashwell, and then, by a south-westerly turn, reaches the Roman Way in the parish of Hinxworth. It runs along this second old road southward, only as far as Radwell, and then takes a long irregular course across country west-south-west to north of Hexton, including over a mile again along the Icknield Way (up to Telegraph Hill). Thence it runs irregularly southward, across the Chalk, to north of Harpenden, then turning westward, with a great northerly bow to the Buckinghamshire boundary at Little Gaddesden.

The two counties are then in touch westward to around Puttenham, and thence the western border of Hertfordshire goes with the irregular eastern border of Buckinghamshire, above described, south-westward to the Colne.

It is clear, therefore, that the boundaries of the two counties are for the most part of an artificial character, that is, are based on no natural feature of river, hill, or valley. They may be described as accidental and void of meaning, except where a river has been followed, as along the Thames, the Ouse, and other smaller streams with Buckinghamshire, and along the Lea and the Stort with Hertfordshire.

Taking the two counties together, the only long stretches of river-boundary are on the south, from Fawley parish to near Rickmansworth, and on the east, from Waltham Cross to near Bishop's Stortford. The division between the counties is unexplainable by any natural feature, as also is the boundary of both with Bedfordshire. These matters are clearly in the domain of the antiquary, not of the geographer. It is notable that Hertfordshire has a strong partiality for Roman roads on its northern border.

POPULATION.

We are dealing now with two rural counties, although they are in part residential as regards London. Not one of the great towns of the

Kingdom occurs within the Boundaries of Buckinghamshire and Hertfordshire. Nor does any one of their towns reach the dignity of a County Borough. Only one has a population of 40,000 and only two others reach 20,000.

There are, however, a goodly number of small towns, and the census of 1911 credits Buckinghamshire with 11 Boroughs or Urban Districts, and Hertfordshire with 20, which became 21 in 1913, by the addition of Chorleywood, and 22 later by the addition of Letchworth, as Urban Districts.

It will be seen from the following table that whilst Buckinghamshire is the larger county Hertfordshire is the more populous. The former had, in 1911, over 2 acres to each person, whilst the latter had just short of $1\frac{1}{3}$.

	Acres.	Population, 1911.	Population, 1914.
Buckinghamshire ...	479,360	219,583	225,207
Hertfordshire	404,523	311,321	324,567

The figures on the right are from the Registrar-General.

In Buckinghamshire the following towns have populations of over 10,000 : High Wycombe, 20,390 (21,066) ; Slough, 14,985 (15,870) ; and Aylesbury, 11,048 (11,502). Hertfordshire has many more towns of the sort, but only one of over 20,000 population—Watford with 40,953 (43,831) ; St. Albans has 18,132 (25,624) ; Cheshunt, 12,956 (13,119) ; Hemel Hempstead, 12,888 (13,295) ; East Barnet Valley, 12,381 (12,955) ; Hitchin, 11,905 (12,366) ; Barnet, 10,440 (11,871) ; and Hertford, 10,384 (10,650).

The figures in brackets have been furnished by the Registrar-General, and stand for the estimated populations in the middle of 1914, the latest period up to which an estimate has been formed, the war having made it impossible to go further. So far figures can be given only with elimination of the military element : probably some camps had a population in excess of many of the boroughs.

SURFACE-LEVELS.

In *Buckinghamshire* there is a range of level of nearly 800 feet, from under 50 feet above Ordnance Datum by the Thames, on the extreme south, in the parish of Wyrardisbury, to 834 feet at Aston Hill, in the parish of Aston Clinton, on the Chiltern Range. Besides this, other high points along this great Chalk Escarpment are at Great Wood, Bledlow, over 800 feet ; east of Prince's Risborough, 813, and the same at Pulpit Hill, Great Kimble ; at Lodge Hill, in the parish of Ellesborough, 826 ; and south-east of Ivinghoe, 811. The projecting mass of Ivinghoe Beacon, one of the most beautiful of our Chalk-hills, reaches only 762 feet.

In *Hertfordshire* there is a range of level over 700 feet, from about 60 feet by the Lea at Waltham Cross, on the south-west, to 769 on the Chalk Escarpment at Martin Hill, in the parish of Tring, on the north-west. Further north-eastward the higher points of the Chalk-range are 619 feet, at Aldbury Common ; 602 at Telegraph Hill, in the parish of Lilley ; 539 at Great Offley ; and 535 at Therfield. This lessening of height contrasts with the more even and higher figures of the highest points in Buckinghamshire.

RIVERS.

Both counties are in two of the great river-basins of the country, those of the Thames and of the Ouse; but Buckinghamshire alone touches the River Thames, Hertfordshire being concerned only with southerly flowing tributaries in two sub-basins, those of the Colne and of the Lea, both of which have several sub-tributaries.

Whilst in Hertfordshire the comparatively small amount of northerly flowing water finds its way to the Ouse, except for a small amount from the Gault-tract of Puttenham, which goes westward to the Thame; in Buckinghamshire there is a large part of the sub-basin of the Thame, and much of the head-waters of the Ouse.

In tracing the rivers of the two counties I have been guided by the new series of Ordnance Maps, on the scale of an inch to the mile.

Basin of the Thames, Main Stream and Small Tributaries.

Dealing first with the chief river, which forms our extreme southern boundary, the various tributaries will be noticed from west to east.

The first is a very short stream (in Buckinghamshire) from the south of Fingest, which flows south to the Thames at Mill End, Hambledon. Probably, as is usual with Chalk-streams, the point of outflow varies seasonally, moving higher up after times of heavy rainfall.

The Wye or *Loudwater* is also a purely Buckinghamshire stream. It is marked as rising in two places, in the Chalk, West Wycombe and Hughenden; but here, too, the top part of the stream must be of the nature of a bourne, with varying outburst. It flows south-east to Wooburn Green and then turns south-westward to Bourne End, where it joins the Thames. In its course down from High Wycombe, where the two component streams join, it receives no tributary.

In that part of Buckinghamshire between a line from Burnham to Dorney eastward to the Colne, there is a number of insignificant streams, from gravels and Tertiary beds, unnamed on the Ordnance Map, wandering through the great gravel-flat and flowing into the Thames at various places.

Sub-basin of the Colne.

The development of the Colne and its tributaries has been dealt with by A. Sutton, in a paper on the River-system of Western Hertfordshire.[1]

The main stream, that is the part which bears the name of *Colne*, is chiefly a Hertfordshire stream, though having its head-waters in Middlesex, as the "Mimmshall Brook," the drainage of the Tertiary tract northward of Barnet, added to by the little "Catherine Bourne," from between Shenley and Ridge, which joins the other branch at Mimms Hall. On reaching the Chalk this head-part of the Colne is noted for its swallow-holes (*see* p. 86). The stream flows northward to Colney Heath, then south-westward, by London Colney and Watford, to Rickmansworth, and then southward to the Thames above Staines.

The Colne has many tributaries; but those on its left bank within our district consist only of short nameless streams from the Tertiary beds and their overlying gravel. On the right bank, on the other hand, there are tributary-rivers of some length and importance.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1907, vol. xiii, pt. 1, pp. 1–4.

1. The highest of these is the *Ver*, and this is bigger than the Colne itself at the junction, a matter which has been dealt with at some length by J. HOPKINSON,[1] who concludes "that the Colne must at some former time have been a much larger stream than it is now," whilst the Ver has not "materially decreased." It is a purely Hertfordshire stream, mapped as rising at Markyatestreet; but, as with other Chalk-streams, its starting point is subject to seasonal variations, or, in other words, its upper part is a Bourne. It flows south-eastward, by Redbourn to St. Albans, the Roman name of which city (Verulamium) betrays its origin. Then it turns southward, by Park Street, to join the Colne at Colney Street, without receiving any tributary along its whole course.

2. *The Gade*, another Hertfordshire Chalk-stream, is mapped as rising in the parish of Studham, eastward of Little Gaddesden; but the point of issue varies with the season. The stream runs in a general south-south-easterly direction, by Great Gaddesden, Hemel Hempstead, and King's Langley, with three gentle turns, to Cassiobury Park, after passing through which it takes a short south-western course to the Colne above Rickmansworth.

The Gade has only one tributary; but that is a large one, the *Bulbourne* being probably the bigger stream of the two, as is the case with the Colne and the Ver. It is also a Chalk-stream, confined to Hertfordshire, and is mapped as rising at Dudswell, north-west of Northchurch; but, of course, this higher part is a bourne. It flows south-eastward, by Berkhampstead, to join the other branch of the river, the Gade, at Two Waters, south of Hemel Hempstead.

The Bulbourne itself has a tributary, small, but oft described of importance, though ignominiously dubbed "Bourne Gutter," on the Ordnance Map. This is the well-known Hertfordshire Bourne (*see* p. 71), though in its higher part it seems to belong equally to Buckinghamshire. It is usually dry; but when the intermittent stream flows its short course is eastward from near White Hill to Bourne End, where it joins the Bulbourne. Each of our two counties therefore has a place named Bourne End.

3. *The Chess*, another Chalk-stream, belongs to both counties, and forms their boundary for nearly three miles in the middle of its course. Starting at Chesham, a meeting place of several valleys, it flows more or less south-westward, by Chenies, to join the Colne at Rickmansworth. It has no tributary.

4. *The Misbourn* is a Buckinghamshire Chalk-stream, mapped as rising at Mobwell, just above Great Missenden; and DR. R. L. SHERLOCK tells me that the rise is generally in a gravel-pit, between road and railway; but probably varies in this, as in other Chalk-streams. The stream flows in a general south-easterly direction, past Little Missenden, Amersham, and Chalfont St. Giles and St. Peter, to join the Colne just south-east of Denham. Though therefore of considerable length, it has no tributary.

Dr. SHERLOCK also says that water used to rise at Rignall, a little way up the western or Hampden branch of the valley, and a small well at the house (about 450 feet above Ordnance Datum) is 48 feet deep, with an average depth to water of 34 feet.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1892, vol. vi, pp. xxix–xxxii, quoted later on.

5. *The Alder Bourne* is a short, small stream, or collection of streams, from Tertiary beds and gravel, starting from north of Fulmer and flowing south-eastward to the Colne at Uxbridge Moor.

Sub-basin of the Lea.

The *Lea* rises outside our area, in Bedfordshire, starting from the lower part of the Chalk at Leagrave Marsh, north-west of Luton. Thence it flows south-eastward through Luton, into Hertfordshire, north of Harpenden, and continues in that direction, by Wheathampstead, to Hatfield, then turning eastward and north-eastward to Hertford and Ware, where it turns south-eastward for a short way, and then takes its southerly course to the Thames, almost at once leaving the Chalk, over which it has run throughout, by Hoddesdon, and entering the Tertiary tract, forming the border of the county for about six miles, by Broxbourne, Wormley, and Cheshunt, down to Waltham Cross.

The Lea has many tributaries, though none for many miles from its start, not indeed until it passes Hatfield, and then, on the right (or southern) bank there are only small short streams, flowing northward from the escarpment of the Tertiary beds, with its cappings of gravel. The like occur too where the Lea takes to its southerly course through the Tertiary tract, where there are small streams from the more or less Drift-covered slope of London Clay that form the right or western side of the valley. These streams are all nameless, except the *Cuffley Brook*, which, rising by Ponsbourne Park, flows southward, is reinforced by the stream from Northaw, then passes into Middlesex, turns eastward, and, flowing roughly parallel and near to the county-boundary, reaches the Lea Navigation at Enfield Lock.

On its left side, however, the Lea receives many tributaries of considerable size, so that of the two chief rivers that flow across the wide Chalk-tract of our district, one, the Colne, has all its large tributaries on the right side, whilst the other, the Lea, has them on the left side; and in both cases there are only insignificant streams coming in on the other sides.

1. *The Maran* or *Mimram.* Except for tiny streamlets in the Drift-flat just below Hatfield, this is the first of the tributaries on the left bank. It is mapped as rising in the parish of St. Pauls Walden, about 1½ miles westward of the church; but probably its point of outflow varies seasonally, as with other Chalk streams. It winds in a general south-south-easterly direction, by Welwyn, Digswell, and Hertingfordbury, and joins the Lea between that place and Hertford. Its only tributaries are a stream of about half a mile in length, from a spring down to Kimpton Mill, and a small stream from the Drift-flat westward of Hertingfordbury, which joins just below that village and only half a mile above the junction of the Maran with the Lea.

2. *The Beane*, another Chalk-stream, has its head-waters in various places; on the west in the parish of Weston, about half a mile south of Church End; on the north at Rushden; and on the east at Broadfield and Cottered. But whether these are permanent outflows, as mapped, or not is a question. J. M. Wood tells me (1920) that the streams are said to be intermittent. The various streamlets, flowing from all directions except south, join near Luffenhall, and the resultant

stream then flows southward, and, passing Walkern, Aston, Witton and Stapleford, joins the Lea at Bengeo (Hertford).

There is a tributary on the right, rising at the southern end of Stevenage and flowing south-eastward to the Beane above Walton. The *Old Bourne*, another tributary, on the left, is mapped as rising south-eastward of Cottered, whence it flows irregularly south-westward, by Little Munden and Sacombe, to the Beane in Woodhall Park. This itself has a branch, mapped as rising near Cherry Green, in the parish of Westmill, and flowing south to Great Munden and then south-westward to Little Munden.

3. *The Rib*, with its many tributaries, is a fairly composite river, perhaps because it is not by any means a purely chalk-stream, but gets much of its water from the drainage of a broad tract of Glacial Drift, chiefly Boulder Clay, and so misses the usual simple character of a Chalk-stream. The course of the upper part of the Rib and its affluent, the Quin, has been described in some detail by R. P. Greg and R. B. Croft, and the rest of the Rib by A. G. Puller.[1]

The name-stream is mapped as starting near Chapel Green, in the parish of Therfield, and on the border of Buckland and Reed, at which latter place it is within half a mile of one of the head-waters of the tributary Quin. Its course is a little east of south, by Buntingford and Westmill to Standon, whence it is southward for some four miles, then curving round south-westward, by Wadesmill, to the Lea on the eastern side of Bengeo (Hertford).

On the right side there are many short tributaries, from near Mill End, Sandon (practically one of the head-waters) downward. On the left side there are only a few short streamlets; but there is the *Quin*, which is about as long as the main stream above the junction. This is mapped as rising at Barkway, with a branch from the border of Buckland and Reed (but little east of one of the head-waters of the Rib) on the west, and another from near Nuthampstead on the east. The combined stream flows south, through Braughing, just below which village it joins the Rib.

The meeting of so many streams (the Lea, the Maran, the Beane, and the Rib) at Hertford is remarkable, followed as it is by the accession of two other streams within a few miles, also on the left side of the Lea.

4. *The Ash* is mapped as rising near Barleycroft End, Furneux Pelham, whence, reinforced by short streamlets on either side, it flows southward, by the two parishes and the two hamlets that rejoice in the name of Hadham (with prefix or affix in each case). It then turns south-westward, still following the Drift-covered boundary of the Tertiary beds, and joins the Lea about a mile below Ware.

The course of the Ash has been described at length by R. Gosslin.[2]

5. *The Stort.* We now come to the last of the many rivers tributary to the Lea, one which, rising in Essex, near Clavering, has a southerly flow of several miles before reaching Hertfordshire, which it does some two miles above Bishop's Stortford, when it at once becomes the county-boundary. It continues its southerly flow to a little below Sawbridgeworth, where it turns west-south-west and joins the Lea eastward of Hoddesdon. Like the Lea it has been made a navigable stream for

[1] *Trans. Herts. Nat. Hist. Soc.*, 1883, vol. ii, pt. 3, pp. 126–136.
[2] *Ibid.*, pp. 137–140.

some way, and the "Stort Navigation" has been improved lately by the Commissioners of the Lea, in whose charge it is. J. M. Wood tells me that it used to be navigable up to Bishop's Stortford; then it fell into disuse; now (1920) the works and locks are again complete up to Sawbridgeworth.

Sub-basin of the Thame.

Whilst the above-noted tributaries have a general southerly or south-easterly flow, with the dip of the beds, the Thame has more of a south-westerly one, along the strike of the beds. Its higher part is in the middle part of Buckinghamshire.

The main stream is mapped as rising at North End, Stewkley, with a branch west of the village; but on the old Ordnance Map (46, S.W.) the stream is shown no higher than by the main village. As this tract consists of Oxford Clay, and possibly Kimeridge Clay, with a covering of Drift, it is likely that in dry seasons the surface-drainage may not result in a stream until the latter point is reached, whilst in wet seasons it may extend up to the former point. The old mappers may have done their work in the dry, the new ones in the wet.

From Stewkley the stream flows for several miles over a broad tract of Kimeridge Clay, and for some way (about five miles) close to where the Gault is conjectured to come on above. As there is much drift, the boundaries between the three clays (Oxford Clay, Kimeridge Clay, and Gault) are all the more doubtful, and, as the Drift consists largely of Boulder Clay, the stream is for the most part the result of the drainage of a clay-tract. Leaving the neighbourhood of the Gault, it passes the villages of Hardwick, Lower Winchendon and Chearsley, becomes the county-boundary in the southern part of the parish of Long Crendon, and then flows westward, by Shabbington, to the southern end of the parish of Worminghall, where it enters Oxfordshire, joining the Thames at Dorchester, in that county. Throughout it is a clay-stream, except for some of the tributary water. The main stream is everywhere based on Kimeridge Clay.

On the left side there are three tributaries in Buckinghamshire. The first is the *Thistle Brook*, almost as long as the main stream above the junction and of much more composite origin; indeed it is not easy to trace on the map the manifold branches of this and other streams. Starting with the drainage of the Gault clay-tract, between Marsworth and Mentmore, in Buckinghamshire, reinforced from a Chalk-spring at Tring, in Hertfordshire, the brook takes a westerly course across Gault and Kimeridge Clay, to the Thame, north-west of Aylesbury.

About a mile below this another tributary joins, from the south and south-east. It starts from Chalk-springs (and perhaps from Upper Greensand) in the neighbourhood of Aston Clinton and Wendover, picks up the drainage of the Gault-tract and the water from springs from the Portland Beds at Bierton, on the right, flows round the southern part of Aylesbury, and gets a little more water from Portland Beds on the left.

The last tributary of the Thame on the left with which we are concerned is *Ford Brook*, another composite stream, which starts from Chalk-springs near Ellesborough, and, in its more or less westerly course, receives water on the south from the Upper Greensand, with

the drainage of the Gault, besides a little from the Portland Beds near Haddenham, on the north, and joins the Thame just above the town of that name.

The Cottle Brook (a name unfortunately given also to another stream just to the west, on the Ordnance Map 237), is practically an arm of the Ford Brook, which it joins not much more than a mile above the junction of the latter with the Thame. It starts from Chalk springs at Prince's Risborough, Horsenden, and Bledlow, in Buckinghamshire, and at Chinnor, in Oxfordshire, and like the above streams is reinforced from the Upper Greensand and the clay-tract of the Gault. It joins the Ford Brook at the western end of the parish of Kingsey, soon after reaching the outcrop of the Portland Beds.

On the right, the Thame receives no tributary of note before the small stream that results from the drainage of the tract of Kimeridge Clay northward of Fleet Marston, and joins the Thame southward of that place. Apparently there is a slight accession (? occasionally) from a spring rising from the Portland Sand at Pitchcott.

Another tributary starts from the drainage of the Kimeridge Clay southward of Waddesdon, and, in its general south-south-westerly course over that formation, is added to by springs from the Portland Beds of the various outliers between which it passes. The short branch from near Dorton must contribute some water from the Calcareous Grit. The stream joins the Thame just south of the village of Chearsley.

Below this are some short streamlets, and then a longer one, starting at springs along the southern part of the outlier of Shotover Sand and Portland Stone at Brill, and flowing southward, over the underlying clays, to the Thame between Ickford and Worminghall.

Westward of this we have only the head-waters of streams that pass through Oxfordshire to the Thame. One comes from the drainage of the Oxford Clay southward from near Oakley. Then there is the *Holton Brook*, the upper part of which is called *Dames Brook*, the drainage of the tract of Oxford and Ampthill Clays round Boarstall, probably added to by springs from the outlier of Shotover Sand and Portland Stone at Muswell Hill, and from Calcareous Grit.

The Ray.

The head-waters of this river are in Buckinghamshire, in the multitude of streams north-west of Quainton, and thence by Grendon Underwood to Marsh Gibbon, but the stream passes into Oxfordshire at the southern end of the latter parish.

Basin of the Ouse.

The River Ouse first reaches Buckinghamshire, as a small stream, at Biddlesden, and thence, in a curving course, first westward and then eastward, forms the boundary, by Turweston and Westbury, to Water Stratford. It then passes eastward through the county, by Buckingham, Thornton, Stony Stratford, Wolverton, between Great and Little Linford, to Newport Pagnell, in a series of curves that takes it slightly northward. Then it curves on northward to Olney, and thence eastward to Newton Blossomville, where the northerly course is again taken, and after about two miles (again forming the county-boundary) the river flows into Bedfordshire.

On the left bank, where the Ouse is the county-boundary, there are at first, as must be the case near the head-waters of a river, only small short streams, which join at Biddlesden, Westbury and Water Stratford. Then there is a rather longer one (*Oxford Water* ?) starting in two branches northward of Stowe Park, flowing by its western side, and joining southward. Another short streamlet joins just above Buckingham, and yet another over two miles below that town.

Just above Thornton there comes in a longer and composite stream, made up of various branches in the neighbourhood of Lillingstone (Dayrell and Lovell), and from beyond, in Northamptonshire. Then there are other small streams from that county.

All the above-noted streams result largely from the drainage of a tract of Boulder Clay, reinforced probably by springs from the Great Oolite, which is cut down into along great parts of the valleys.

Then comes the only tributary of any importance on this (left) side, the *Tove*, which forms the county-boundary for some miles. It rises far beyond Buckinghamshire, and itself has a number of small tributaries, only a few of which come from the Buckinghamshire border.

A small stream, starting in various places in the parish of Hanslope, joins the Ouse opposite Wolverton, and another composite one joins east of Stoke Goldington, beyond which we have only very short streams above and below Olney.

Turning to the right side of the Ouse, the highest two tributaries that join in Buckinghamshire are very short streamlets, at Radclive and just below Buckingham.

The Claydon Brook is the first tributary to the Ouse of any importance. It is a very composite stream, or rather collection of streams. The largest branch rises east and west of Oving, partly from springs from the Portland Beds, and flows northward to near Winslow, where it is joined by another stream from the east, the drainage of the clay-tract of Mursley and Swanbourne ; the combined stream then flowing westward for about two miles, receiving an addition from the neighbourhood of North Marston and Hogshaw ; and then turning north-westward, along the northern boundary of the parish of Steeple Claydon, receiving another addition from the neighbourhood of the Horwoods, and finally taking a northerly course to the Ouse, about two miles east of Buckingham, with a small easterly addition from Nash, just before joining the main river.

The westerly branch rises in Oxfordshire, and, flowing in an easterly course, enters Buckinghamshire south of Chetwode, and passes by Twyford to Steeple Claydon, where it turns northward to join the other and main part of the brook, at the northern part of that parish. It has tributaries from Middle and East Claydon, joining at and below Steeple Claydon.

The Claydon Brook is mostly the drainage of a large tract of clay.

The next tributary of the Ouse is a small one from Whaddon, whence it flows northward to Calverton. Then a stream from around the Shenleys flows northward to New Bradwell.

The Ouzel or *Lovat*. This, the chief tributary joining the Ouse in our district, starts from a long set of springs from the Chalk, along the foot of the escarpment near Pitstone, Ivinghoe and Edlesborough,

besides others beyond, in Bedfordshire. The resultant streams are reinforced by the drainage of the Gault, and they join up at various places, until they combine into one stream just north of Slapton, which takes a northerly course and becomes the county-boundary for a few miles, by Grove and Linslade. Continuing northward by Fenny Stratford, Simpson, and Great and Little Woolstone, it joins the Ouse at Newport Pagnell.

On the left side there are many small tributaries, almost wholly the product of the drainage of a great clay-tract (Boulder Clay, Gault and Kimeridge Clay), which join (either the river or the canal) at a number of places.

The right side is at first in Bedfordshire. The first contribution from Buckinghamshire is in the form of short streamlets starting from Lower Greensand springs around Great, Little and Bow Brickhill, joining north-west of Linslade and westward of those places.

Beyond this we again have streams from clay-drainage, firstly from around Wavendon, and then in the form of a longer stream (*Crawley Brook* of the old map) mainly belonging to Bedfordshire and starting from Lower Greensand springs in that county. It enters Buckinghamshire in the parish of Broughton and joins the Ouzel over a mile below that village.

The Chicheley Brook, the resultant of the drainage from Boulder Clay and Kimeridge Clay around North Crawley, winds in a general easterly direction (but at one part north and at another south) to the Ouse just below Newport Pagnell.

Below this there are only short streamlets, from Jurassic limestone and from clay-drainage, joining the Ouse at four places, up to where it leaves our district.

The Ivel. It is only the head-water of this tributary of the Ouse that is in our district. Starting from Chalk-springs at Baldock the stream, in a north-westerly course of about $1\frac{1}{2}$ miles, passes out of the county at Radwell, going northward through Bedfordshire to the Ouse.

In this case, however, as in others above noted, there is a branch which is longer than the main stream, and also more in the direct line of flow, namely the *Hiz*, initially another Chalk-stream. Starting at the springs of Well Head, southward of Hitchin, it flows through that town and past Ickleford, a little below which it becomes the county-boundary for a short way, and then passes wholly into Bedfordshire. The Hiz, moreover, asserts its superiority over the Ivel by having two named tributaries. The one on the left side is the *Oughton*, rising from the springs of Oughton Head, westward of Hitchin, and with a north-easterly course of about two miles to Ickleford. The other, on the right side, is the *Purwell*, the higher part of which rejoices in a second name, *Ippollitts Brook*, and its starting point probably varies, or in other words it is a bourne. At times there would seem to be an outflow south-west of Stevenage, near Rush Green, judging by the mapping of a narrow strip of Alluvium for some way down the valley. The stream is shown on the map as continuous from Ippollitts northward, passing half round Hitchin, on the east of the town, by Nine Springs, and joining the Hiz on the north of the town. This stream is therefore longer than the Hiz itself.

The Rhee, one of the arms of the Cam, a tributary of the Ouse, starts in Hertfordshire, at the Chalk-springs of Ashwell, but soon passes out of the county. A tributary stream rises north-west of Barley, and also passes out of Hertfordshire very soon.

CHIEF SUPPLIES.

The one great supply that we have to deal with is that of the Metropolitan Water Board, with its nine wells in Hertfordshire, all in the valley of the Lea, besides the historic Chadwell Spring (*see* pp. 55–61) and this, of course, is far ahead of any other set of works in our district with a yield of many million gallons a day. I understand from J. M. Wood, that in all but the most southerly of these wells the water-level recovers itself in normal seasons, when summer-pumping slacks off, and that in wet seasons it recovers rapidly.

After this come four supplies of over a million gallons a day, all in Hertfordshire. The Colne Valley Co. (3,250,000), the Barnet District Co. (2,113,000), and the Rickmansworth and Uxbridge Co. (1,153,000), all of which give much of their supply to Middlesex, and the last partly to Buckinghamshire also, whilst the Watford Council's supply (about 1,200,000) is confined to Hertfordshire.

Then there are only three other supplies that exceed half a million gallons a day: Slough (750,000), St. Albans (696,000), and the Chiltern Hills Co. (608,000). All these figures are from the Local Government Board's Return of 1915, and the source of all these supplies is the Chalk.

The one case of any note where our district gets a supply from outside is Eton, which gets it from the Windsor Corporation Works, and this is a river-supply.

It is clear from the above that Hertfordshire is in a peculiar position in the matter of water-supply. In the case of other counties that have been dealt with in the set of Water Memoirs of course there are many instances where a supply got at one part of the county is taken to another part. This sort of thing must occur, for, as a rule, the larger places cannot get the whole of their supply from their own district, but have to go further afield, to smaller places, where the supply is far in excess of the demand. It is usual, however, for Parliament to insist on such supplies being used also for the benefit of the places from which they are taken.

With Hertfordshire matters are different; the set of wells belonging to the Metropolitan Water Board, with the Chadwell Spring, are used mostly for the supply of Middlesex and London. The next two largest undertakings, those of the Colne Valley Co. and the Barnet District Co., are also largely, or chiefly used, for the supply of Middlesex, and the rather smaller works of the Rickmansworth and Uxbridge Co. also serve outside Hertfordshire.

This has given rise to much controversy, and Hertfordshire has often protested against further water being taken from within its borders for the supply of outside places. This Memoir is not the place for a discussion on this subject, but it is right to notice it. However, county-boundaries are hardly to be considered as of the highest importance in large questions of water-supply.

It is questionable perhaps whether this Memoir should not be entitled Water Supply *in* rather than *of* Hertfordshire.

GEOLOGIC FORMATIONS.

GENERAL REMARKS.

The chief of the great geologic series of formations with which we have to deal in the two counties is the *Cretaceous;* but in Buckinghamshire we have a large area of the underlying *Jurassic* series, and in both counties a goodly tract of the overlying *Eocene Tertiaries.* The *Pleistocene* deposits, as a whole, range irregularly over all the older beds; but the various divisions are to a great extent more local. Between these last and the Eocene beds there is a great gap, and similar gaps occur between the Cretaceous and the Jurassic rocks, and, deep underground, between the Jurassic rocks and the Palæozoic formations.

In the following table the formations are given in descending order, the names in the right column being those of the beds distinguished by colour on the Geological Survey Maps, though in some cases various divisions have not yet been shown in our counties.

The figures in brackets attached to the various divisions are their thicknesses in feet in the two counties, as far as known, and these are taken, for the most part, from the Memoir "On the Thicknesses of Strata," 1916.

The letters B and H. show the counties in which the beds occur at the surface, and from these it will be seen that Buckinghamshire has the wider range of formations, nothing below the Gault cropping out in Hertfordshire, whilst in Buckinghamshire there will probably not be an omission, when the Drift has been mapped throughout.

Recent ...	——	Alluvium	B.	H.
Pleistocene	Valley [or River] Drift ...	Brickearth	B.	H.
		Gravel	B.	H.
	Glacial Drift	Boulder Clay	B.	H.
		Loam	?	H.
		Gravel	?	H.
	High level Gravels	Plateau Gravel of various ages ...	B.	H.
		Pebble Gravel ...	B.	?
	Surface Deposits, over the Chalk, of doubtful age.	Plateau Brickearth ...	B.	H.
		Clay with Flints ...	B.	H.
Eocene ...	——	London Clay (up to 200, perhaps more)	B.	H.
		Reading Beds (31-78)	B.	H.
Cretaceous	Chalk	Upper Chalk (up to 330)	B.	H.
		Middle Chalk (200 to 220 or more) ...	B.	H.
		Lower Chalk (180 or more)	B.	H.
		Chalk Marl (included in above)	B.	H.
	Selbornian	Upper Greensand (0 to 40)	B.	?
		Gault (160 to 248) ...	B.	H.
	——	Lower Greensand (0 to 250)	B.	—
	——	Wealden, Shotover Sands (up to 45) ...	B.	

Jurassic ...	Upper Oolites	Purbeck Beds (20 to 30)	B.	—
		Portland Stone } (60)	B.	—
		Portland Sand }	B.	—
		Kimeridge Clay (100)	B.	—
	Middle Oolites	Calcareous Grit } (40 to	B.	—
		Ampthill Clay } 50)	B.	—
		Oxford Clay (420) ...	B.	—
	Lower Oolites	Cornbrash (5 to 8 or more)	B.	—
		Great Oolite— Forest Marble or Great Oolite Clay (13 to 40) ... Limestone (15 to 25)	B.	—
		Upper Estuarine Series (15 to 33)	B.	—
		Northampton Sand, including Lower Estuarine Series (8 to 27)	B.	—
		Upper Lias Clay (120)	B.	—

The Ampthill Clay (part of the Corallian) is shown only on the new map with Oxford in the centre.

The following have been proved, by deep borings, to occur underground, though not coming to the surface.

Middle and Lower Lias, in Bucks. (to 22 and to 240½).

Devonian, in Herts.

Silurian, Ludlow in Bucks, Wenlock, in Herts.

Cambrian, Lower Tremadoc, in Bucks.

AREAS AT THE SURFACE.

In 1893 W. Topley gave, in a tabular form, a set of measurements of the areas of the various geologic formations at the surface in the River Basins of the Thames drainage-system.[1] The following account of those River Basins with which this Memoir is chiefly concerned is made up from this table, with some additions from a fuller account, which, though printed, cannot be said to have been published : it was the basis on which the table was drawn up.

The basin of the Thame, on the west, is largely out of our district : practically we have to do only with the Upper Cretaceous part, and of that, moreover, much is in Oxfordshire.

The basin of the Lea, on the east, except for most of its tributaries, is also largely out of our bounds, and we are concenred with little but the Chalk-area (and part of that is in Bedfordshire). The lowest notable tributary, the Stort, is for the most part not in Hertfordshire ; nevertheless it is well to include both these areas.

The small basin of the Loudwater and the comparatively large basin of the Colne (with its five tributaries) belong wholly to Buckinghamshire and Hertfordshire. Four tributaries of the Lea, the Mimram, the Beane, the Rib and the Ash are wholly, or almost wholly, in Hertfordshire.

To get the area in which the Chalk is bare, of course the area of superficial beds over the Chalk must be subtracted from that of the

[1] *R. Comm. Metrop. Water Supply, Appendices.* Table opp. p. 414.

Chalk as a whole, in the following tables in which the figures stand for square miles :—

Basin of the Thame, 265·8 square miles.

Superficial Beds over Chalk	Valley Gravel	·6
	Clay with flints	3·1
Chalk		42·
Upper Greensand		17·7
Gault		92·27
Lower Greensand		6·2
Purbeck Beds		1·6
Portland Beds		24·5
Kimeridge Clay		53·2
Corallian Beds (*?not including Ampthill Clay*)		19·2
Oxford Clay		8·6

Area between the Basins of the Thame and of the Loudwater, drained by the Bensington Brook, the Hambledon Brook, etc., direct into the Thames, 150·8 square miles.

Alluvium over Gault and Upper Greensand		·45
Superficial Beds over Chalk, 57·2	Alluvium	4·
	Valley Gravel	12·2
	Hill Gravels	11·2
	Loam	2·
	Clay with flints	27·8
London Clay		·1
Reading Beds		5·4
Chalk		138·3
Upper Greensand		4·4
Gault		2·6

Basin of the Loudwater, 56·3 square miles.

Superficial Beds over Chalk, 27·8	Alluvium	1·3
	Valley Gravel	4·6
	Hill Gravels	2·1
	Loam	13·
	Clay with flints	6·8
London Clay		·1(—)
Reading Beds		2·6
Chalk		53·6

Area between the Basins of the Loudwater and of the Colne, 37·8 square miles.

Alluvium over London Clay and Reading Beds		·9
Over Chalk, 2·6	Valley Gravels	2·5
	Hill Gravels	·1
London Clay		20·1
Reading Beds		12·2
Chalk		5·5

Basin of the Colne, apart from tributaries.

Alluvium over Reading Beds and London Clay		19·8
Valley Gravel and Brickearth over London Clay		8·5
Superficial Beds over Chalk, 57·7	Alluvium	3·4
	Valley Gravel	2·5
	Hill Gravels	28·4
	Loam	16·5
	Clay with flints	3·4
	Boulder Clay	3·5
London Clay		74·2
Reading Beds		22·7
Chalk...		87·7

These figures are got by subtraction of the total for the tributaries (Ver, Gade, Bulbourne, Chess and Misbourn) from the figures given for the Colne Basin as a whole.

In 1896 J. HOPKINSON gave a very much less figure for the Chalk ; but perhaps his area for the Colne is not the same as that taken above. He defines it as "above Harefield," and his figure is only 35 square miles. *Trans. Herts. Nat. Hist. Soc.*, vol. ix, pt. 2, p. 46.

Basin of the Ver (tributary of the Colne), 5·11 square miles.

Superficial Beds over Chalk, 36·1	Alluvium	1·4
	Valley Gravel... ...	1·7
	Hill Gravels	2·
	Loam	4·7
	Clay with flints ...	26·2
	Boulder Clay	·1
Reading Beds		·3
Chalk		50·8

J. Hopkinson gives the Chalk area as only 36 square miles. *Trans. Herts. Nat. Hist. Soc.*, vol. ix, p. 46.

Basin of the Gade (tributary of the Colne), 49·7 square miles.

Superficial Beds over Chalk, 33·9	Alluvium	1·2
	Valley Gravel... ...	1·3
	Hill Gravels	10·3
	Loam	4·4
	Clay with flints ...	16·7
Reading Beds		·4
Chalk		49·3

Hopkinson gives the figure 88 for the Chalk of the Gade; but this clearly includes the Bulbourne.

Basin of the Bulbourne (tributary of the Gade), 26·5 square miles.

Superficial Beds over Chalk, 18·6	Alluvium	·4
	Valley Gravel... ...	4·5
	Hill Gravels	2·
	Loam	2·1
	Clay with flints ...	9·6
Chalk		26·5

Basin of the Chess (tributary of the Colne), 39 square miles.

Superficial Beds over Chalk, 28·6	Alluvium	1·
	Valley Gravel... ...	·2
	Hill Gravels	4·6
	Loam	10·1
	Clay with flints ...	12·7
London Clay		·1 (−)
Reading Beds		·4 (+)
Chalk		38·5

Hopkinson gives the figure 36 for the Chalk of the Chess. Apparently he passes over the Misbourn.

Basin of the Misbourn (tributary of the Colne), 38·1 square miles.

Alluvium over Reading Beds		·5
Superficial Beds over Chalk, 16·8	Alluvium	·8
	Valley Gravel... ...	2·9
	Hill Gravels	2·3
	Loam	4·6
	Clay with flints ...	6·2
London Clay		1·
Reading Beds		4·7
Chalk		32·4

Basin of the Lea, excluding tributaries, 322·6 square miles.

Superficial Beds over Chalk, 40·8	Alluvium	3·5
	Valley Gravel... ...	2·9
	Hill Gravels	11·
	Loam	4·5
	Clay with flints ...	7·4
	Boulder Clay	11·5
London Clay		151·9
Reading Beds		7·9
Chalk		62·8

These figures have been arrived at by subtracting those given for the tributaries from the figure given for the Lea Basin as a whole.

Hopkinson gives 67 square miles for the Chalk of the Lea proper. *Trans. Herts. Nat. Hist. Soc.*, vol. ix, p. 46.

Basin of the Mimram (tributary of the Lea), 48·1 square miles.

Superficial Beds over Chalk, 26·5	Alluvium	·9 +
	Valley Gravel... ...	·4
	Hill Gravels	8·5
	Loam	·8
	Clay with flints ...	13·9 +
	Boulder Clay	2· +
London Clay		·3
Reading Beds		·7
Chalk		47·1

Hopkinson's figure for the Chalk is only 30.

Basin of the Beane (tributary of the Lea), 70·4 square miles.

Superficial Beds over Chalk, 43·8	Alluvium	·8
	Valley Gravel... ...	·9
	Hill Gravels	12·4
	Loam	·7
	Clay with flints ...	3·4
	Boulder Clay	25·6
London Clay		1·9
Reading Beds		2·4
Chalk		66·1

Hopkinson's figure for the Chalk is 83. Probably his division between the Beane and the Mimram is different from that taken by Topley.

Basin of the Rib, with the Quin (tributary of the Lea) 59·6 square miles.

Superficial Beds over Chalk, 46·7	Alluvium	1·5
	Valley Gravel... ...	2·5
	Hill Gravels	4·9
	Clay with flints ...	·8
	Boulder Clay	37·
London Clay		1·6
Reading Beds		2·8
Chalk		55·3

Hopkinson gives the figure 52 for the Chalk.

Basin of the Ash (tributary of the Lea) 35 square miles.

Superficial Beds over Chalk, 19·1	Alluvium	·9
	Hill Gravels	4·1
	Loam	·1
	Boulder Clay	14·
London Clay		5·7
Reading Beds		6·9
Chalk		22·4

Hopkinson's figure for the Chalk is 35.

Basin of the Stort. Only a small part in Hertfordshire, 106·1 square miles.

Superficial Beds over Chalk, 22·5	Alluvium	·5
	Valley Gravel... ...	·2
	Boulder Clay	19·7
	Hill Gravel	2·1
London Clay		75·7
Reading Beds		5·7
Chalk		24·7

Hopkinson credits the Chalk with 28 square miles. *Trans. Herts. Nat. Hist. Soc.*, vol. ix, p. 46.

WATER-BEARING BEDS.

GENERAL REMARKS.

While the main object of these Water Memoirs is to draw attention to those formations that yield water more or less readily, it must be remembered that the impermeable or relatively impermeable beds also have their uses from the point of view of water, as they hold it up, or keep it down, in the pervious beds, or throw it out of them as springs. The changes in the character of various formations, whereby they are water-bearing in some places, but much less so in others, are likewise of importance in questions of water-supply. Our inquiry therefore necessarily includes some consideration of the whole of the stratigraphy of the counties.

In discussing the formations on which the two counties have to depend for their water-supply, it is convenient to begin at the top of the series, with the varying divisions of the Drift, which are common to both counties, and to work downward to the Jurassic beds, which concern Buckinghamshire only.

Hertfordshire looms more largely in this Memoir because this county has a far more important place than Buckinghamshire in the matter of water-supply: amongst other things it contains many wells of that greatest of water-authorities, the Metropolitan Water Board, and for this reason, as well as from the fact that it comprises a large area of Chalk, the chief water-bearing bed in the southern part of England, it has a voluminous literature on underground waters, springs, etc., owing to the activity of the Hertfordshire Natural History Society, (which has no parallel in Buckinghamshire) and of the Geologists' Association. It has also, for reasons above stated, figured very largely in Royal Commissions and Parliamentary Committees, both productive of much printing. The literature of Hertfordshire has, therefore, been somewhat difficult to deal with, and perhaps some of it may have escaped notice. The controversial part of it, connected with the supply of London, and with questions of consequent depletion, has been passed over, mostly at all events, and of set purpose. That supply is a settled thing, and there seems to be no chance of any further scheme for increasing it by means of fresh wells in Hertfordshire.

GRAVEL AND SAND OF THE DRIFT.

There is no need here to trouble about the geologic classification of the various gravels, etc,, of our two counties: for the present purpose gravel is merely gravel, whatever its particular age or geologic interest.

Our gravels are probably our most permeable beds, and yet are hardly used for public supply; the reason being that they are never of great thickness. It follows, therefore, that to get anything but a small supply works must be extended over a considerable area and in a broad spread of gravel. I know of no such works in our district.

Nevertheless, for small local supplies a tract of gravel is well-suited, provided that there is no risk of surface-pollution. Of course, in the case of the Glacial Gravel, where it occurs beneath Boulder Clay, nature has given good protection from anything on the surface, and good water may be got by wells through the clay. In some cases, too,

the brickearth that sometimes overlies the River Gravel may give a like protection ; but the deposit in this case is both thinner and less impermeable.

Where a tract of gravel occurs at a low level bordering a river, water from the latter may flow into the gravel, unless the river has succeeded in puddling its bed, and fairly large amounts of naturally filtered water may be got.

J. M. Wood writes to me (1920) that some twenty years ago he pumped considerably more than a million gallons a day, for many days, out of the gravel under meadows in the marshes between Hertford and Ware ; and that the water undoubtedly came from the Chalk, as well as from the Lea and the New River. He also alludes to the fact that much water is pumped from gravel at market-gardens and glass houses in the valley of the Lea, particularly in Cheshunt, but that he could not find out how much.

The only large tract of River Gravel, marked on such of the Geological Survey Maps as show the Drift deposits, is in the Valley of the Thames below Maidenhead.

Speaking of this gravel-flat, from Datchet westward to Maidenhead, J. T. Harrison[1] has said, "in some parts it is 30 ft. thick. . . The water in this gravel near Dorney rises gradually from the level of the river northwards, and rarely, if ever, falls below it " ; and he believes that it adds much to the volume of the river, though in greatly varying quantity ; but partly so " in consequence of the level at which the water is maintained between the locks." He advocated the using of this and other gravel-tracts for an additional supply to London.

He believed that, in this case, the water came from the Chalk ; but it has been shown that the old Geologic map was wrong in making the gravel of Dorney, etc., rest on Chalk, later borings having proved the occurrence there of Tertiary beds, as pointed out by me in 1889 ("Geology of London," vol. i, pp 176, 177).

Of the Glacial Gravel there is a large amount on the high ground along the lower part of the valleys of the Misbourn and of the Chess, continuing along the right side of the Colne by Rickmansworth and Watford. It is very much and very irregularly cut into by erosion through to underlying beds along the many dry side-valleys. Where the gravel is underlain by Chalk, of course, in the absence of any clayey or loamy bed, water would pass through from the one to the other ; but where Tertiary beds come next beneath the gravel water would mostly be held up in the latter.

This mass continues north-eastward beyond Watford, by the neighbourhood of St. Albans to Hertford ; but under somewhat different conditions, as here there is in great part a covering of Boulder Clay or of loam, and the gravel in parts reaches down into the valleys of the Colne, of the Lea, and of the Mimram.

READING BEDS.

Where this formation consists to a considerable extent of sand it may afford a supply to houses or small groups of houses ; but it is nowhere thick, and often has only a narrow outcrop : to a great extent, too, it consists of clay, and, as a rule, the beds are irregular.

[1] *Proc. Inst. Civ. Eng.*, 1891, vol. cv, p. 13.

Where there is an outcrop of sand there is a danger from swallow-holes, down which polluted water flows. Many of these occur in the neighbourhood of Aldenham (*see* p. 85). Of course, as with the permeable beds of the Drift, there is a risk of surface-pollution, save where there is a clay-capping, notably where these beds are beneath London Clay. the basement-bed of which, being generally more or less sandy, is also sometimes a source of water. I know of no large amount of water being got anywhere from the Reading Beds in the two counties.

In regard to this however J. M. Wood, who has had long experience of the New River Wells, writes to me (1920) that in the case of large wells, sunk through Tertiary beds into the Chalk, with headings in the latter, he has been led to think that considerable quantities of water sometimes come from the Tertiary beds into fissures in the Chalk. If sand can find its way into the well and heading it follows that water can. He has had experience in trying to shut out such waters, and is doing such work to-day.

CHALK.

General Account.

We now come to the chief water-bearing formation of the south and south-east of England, which indeed has but one rival in the whole of our island, as yielding very large supplies over very large areas, the other being the New Red Sandstone.

In Buckinghamshire and Hertfordshire the Chalk is well developed, both vertically and horizontally ; for it is of great thickness and has a very broad outcrop.

In structure the Chalk is fairly alike from top to bottom ; but there are differences, and these are of a definite kind. The Upper Chalk is white, bedded (the bedding generally marked by layers of flints, mostly in the form of separate nodules of irregular shape, but now and then in more or less continuous sheets) and jointed, that is with fairly vertical planes of division. Between this and the Middle Chalk there is, along the outcrop in the two counties, a thin, hard rocky bed, or set of beds, known as the Chalk Rock. The Middle Chalk is also white, but flintless, or with rare flints in places, and more massively bedded than the Upper Chalk : it also is jointed. At its base is another thin, hard bed, known as the Melbourn Rock. The Lower Chalk beneath is generally white, with a slight tendency to greyness, and of a slightly more clayey character (the divisions above consisting almost wholly of calcium-carbonate, except for flints and occasional earthy layers): immediately beneath the Melbourn Rock there is a notable clayey bed known as the Belemnite Marl. This Lower Chalk has no flints, is more thinly bedded than the divisions above, and its joints are generally of a more irregular character, as contrasted with the even ones of the higher divisions. In the country with which we are dealing the lowest part of the division, the Chalk Marl, is generally of a distinctly clayey character. At its top is another marked hard bed, the Totternhoe Stone, known for many centuries as a building-stone.

Besides the three rocky beds mentioned there are also others of a less marked and much more local character, which need not now be referred to.

For some years past geologists have divided the Chalk in a more elaborate manner than that above described, that is, into zones, characterised by their fossil contents. Of these there are two in the Lower Chalk (the lowest being much the same as the Chalk Marl), two in the Middle Chalk, and no less than seven in the Upper Chalk, according to JUKES-BROWNE'S "Memoir on the Cretaceous Rocks of Britain" (vols, ii, iii). But we are not now concerned with these more minute sub-divisions, which as yet do not enter into the question of water-supply, in our counties, at least: what may be the result of further research is another question.

In the matter of water-supply the Upper Chalk is certainly the great water-yielding division, and for various reasons. It has the great advantage of being the thickest, roughly as much as the Middle and Lower together. From its position at the top of the formation it also has the advantage of the broadest outcrop; for it forms the great dip-slope, from the escarpment down to the oncoming of the overlying Tertiary beds, except where cut through by valleys. By reason of this its *line* of outcrop is in comparatively low ground, toward which water flows underground from the whole of the broad outcrop beyond. Moreover, where there is nothing to check it, water from the Middle Chalk rises up into the beds above where they are at low level, and sometimes the Middle Chalk water may be reinforced by some from the Lower Chalk. The Upper Chalk therefore to some extent depends on the beds below. One may put it that all the water got, by wells near its outcrop or within the Tertiary tract, is from the Upper Chalk.

Whilst the water of the Upper Chalk flows more or less with the direction of the dip, it is not so with that of the lower divisions, where they form the slope of the great escarpment, at the top of which the Upper Chalk comes on. There the plane of saturation is against that of the dip, and with that of the slope of the escarpment, which leads to the occurrence of springs along the base of the range. No one who well knows the fine set of such springs, not only in these counties, but in many others, can doubt that the Lower Chalk yields a great quantity of water, partly, of course, derived from the rain that falls on the Middle Chalk above. This latter division has little independence in the matter of its water, which partly joins that of the Upper Chalk along the dip-slope, and partly that of the Lower Chalk down the much sharper slope of the escarpment or of some valley, though often it is held up by the Belemnite Marl, the top part of the Lower Chalk.

When the Middle and the Lower Chalk together have a broad outcrop, as in the northern part of Hertfordshire, they yield much water, and the following towns get a supply from them: Hitchin, from springs; the Garden City (Letchworth) and Baldock, from the well of the former; and Royston, from a well.

The Chiltern Hills Company, which supplies Aylesbury, Tring, Wendover, and many smaller places, has its wells in Middle and Lower Chalk. It is of the more importance to note these things, as the lower part of the Chalk has often been disparaged as a source of water.

In various cases, too, wells that get a supply from Upper Chalk have borings that go through into Middle and even into Lower Chalk, as at Bushey and Ware, at which places the whole of the Chalk is

pierced, except for the topmost part ; and at Cheshunt and Slough, where the formation is pierced from top to bottom, the supply in the last case being got from Lower Greensand, to a large extent at all events.

J. M. Wood writes however that he thinks that no water is got from the Lower Chalk in the Ware boring, but that there may be a little from the Middle Chalk, and that at Cheshunt (Turnford) also the bulk of the water comes from the Upper Chalk.

The Chalk is essentially a soft limestone, often pure, that is consisting almost wholly of calcium-carbonate ; but, on the other hand, it contains a varying amount of earthy impurity. It varies slightly, too, in structure, generally consisting of very fine grains, but sometimes having stony beds which are in part a crystalline limestone.

The occurrence of clayey layers gives rise to local divisions in the water-system, notably at the junction of the Middle and Lower Chalk, where the clayey Belemnite Marl holds up the water, as proved by the occurrence of springs in places.

Speaking generally, however, the Chalk is one of the most homogeneous of our geologic formations, and despite the above-noted cause of water-partings, must often be taken as a whole in the matter of water.

In 1851 Prof. D. T. Ansted recorded the following results of experiments on the absorbent power of specimens of Hertfordshire Chalk, made under the superintendence of Prof. Miller.[1]

" It seems clear from these experiments, in which the ordinary condition of the bed is very fairly represented, that the upper chalk is capable of receiving into its mass, a quantity of water amounting to more than two gallons for every cubic foot of rock, beyond the quantity usually contained in dry chalk, under ordinary exposure."

Various other details than those now repeated are given in the paper,

In 1853 Prof. E. J. Chapman, in his " Mineralogical Notes," included a short account of " Absorption of Water by Chalk,"[2] founded on a series of experiments, which " confirm in all essential respects the prior investigations of Professor Ansted." The following are some of his results :—

Chalk from Watford :	sp. grav. 2·503.	Water absorbed by 100 parts,			18·76
„ Ware :	„ 2·511	„	„	„	18·68
„ Tring :	„ 2·482	„	„	„	15·12

Two years later S. C. Homersham gave some further particulars of the same sort, from experiments made by Dr. John Smith, as in the following table.[3]

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[1] *Proc. Inst. Civ. Eng.*, vol. ix, p. 368.

[2] *Phil. Mag.* ser. 4, vol. vi, pp. 118, 119.

[3] *Journ. Soc. Arts*, 1855, vol. iii, p. 175.

—	Specific gravity.	Weight per cubic foot.	Weight of specimen in ordinary state, air-dried.	Weight of specimen when absolutely dry, *in vacuo*.	Weight of specimen when fully saturated.	Weight of water in each cubic foot of saturated Chalk.
		lbs. ozs.	grains.	grains.	grains.	lbs.
Upper Chalk, Layhill, near Boxmoor	2·55	158 14	1320·	1316·4	1562	24·987
Middle Chalk, Cow Roast Well (*see* p. 101) 30 ft. down ·	2·55	158 14	1212·6	1210·2	1415	22·731
Middle Chalk, Cow Roast Well, 64 ft. down	2·4	149 9	1659·	1655·2	1920	20·628
Lower Chalk, Tring railway-cutting, near the Chalk Marl	2·47	153 15	1473·	1458·2	1693	21·349
Lower Chalk Marl, Marsworth ...	—	—	1657·6	1620·4	crumbled to pieces.	—

The specimen from near Boxmoor was "taken from near the surface in a dry state, and preserved for six months in a dry atmosphere." It was hard and rather brittle.

The Marsworth specimen contained 22½ per cent. of earthy matter.

Locality and depth of specimens of Chalk.	Weight of Chalk per cubic foot when thoroughly dry.	Weight of Chalk per cubic foot when saturated.	Weight of water in a cubic foot of saturated Chalk.	Gallons of water in a cubic foot of saturated Chalk.	Specific gravity of Chalk irrespective of porosity.
	lbs. ozs.	lbs. ozs.	lbs. ozs.		
Abbot's Langley, 5 ft. deep, from a cutting	110 8	130 6	19 14	1·988	2·601
Abbot's Langley, 40 ft. deep, from a cutting	105 11	127 6	21 11	2·169	2·601
Boxmoor, 5 ft. deep, from a cutting ...	88 9	114 $13\frac{3}{4}$	26 $4\frac{3}{4}$	2·63	2·46
,, 12 ,, ,, ,, ...	85 6	111 $13\frac{3}{4}$	26 3	2·649	2·383
,, 20 ,, ,, ,, ...	90 5	116 $13\frac{1}{2}$	26 $8\frac{1}{2}$	2·655	2·524
Bushey, 4 ft. deep, from lime-kilns ...	106 15	128 2	21 3	2·119	2·6
,, 51 ,, ,, ,, ...	104 6	126 13	22 $6\frac{1}{2}$	2·244	2·618
,, 35 ,, ,, ,, well near lime-kiln	118 $13\frac{1}{2}$	125 $12\frac{3}{4}$	16 $15\frac{1}{4}$	1·695	2·621
Loudwater Mill (?Herts) chalk rock ...	137 $5\frac{3}{4}$	147 $0\frac{1}{4}$	9 $10\frac{1}{2}$	·966	2·609
St. Albans, 29 ft. deep, town well ...	89 7	117 10	28 3	2·823	2·62
,, 46 ,, ,, ...	94 $1\frac{3}{4}$	120 $9\frac{1}{2}$	26 8	2·649	2·629

J. Hopkinson has remarked that "Chalk is a substance which will absorb and retain in its interstices a considerable quantity of water—in fact one third of its bulk—which, except where there are fissures in the chalk, will only gradually ooze through it: the water cannot freely flow until it finds an open channel. And the plane of saturation in the Chalk is not a well-defined surface as is the surface of a sheet of water. In dry weather, when no water is percolating into it, the Chalk is nearly dry at the surface, and gradually . . . it becomes damp, until at last it is so wet that if a piece were cut out and brought to the surface we should see the water slowly ooze out of it. But wherever water runs out of the Chalk, as in springs and wells, it brings away some chalk with it (in solution), and so forms channels near the opening and makes it more porous farther away, enabling it to hold more water than it does in its original state, and that water to flow more freely."[1]

S. C. Homersham has said, "The percolation is facilitated by the varying pressure of the atmosphere. When the barometer is low, the air in the chalk, being expanded, is given out of the fissures and pores, and when the barometer rises, the air, being condensed, enters its pores and carries with it any water that may lie between the . . . planes of stratification . . . Thus every change of the barometer puts in motion the water in the pores of the chalk, and slowly but surely assists the rain from above in reaching the lowermost beds of chalk."[2]

J. M. Wood writes (1920) that, from his experience of the wells of the Metropolitan Water Board in the Valley of the Lea, whenever a large quantity of water is got from the Chalk by means of headings, it comes chiefly from the vertical fissures and the horizontal bedding-planes, and not from the mass of the Chalk (as is also the case in other districts), and that, although the Chalk may be saturated, the sides of the headings soon become comparatively dry after the water is pumped down.

Areas available as a Gathering-ground.

In the middle part of last century it was often the case that the gathering-ground of the Chalk was greatly overestimated, that area being measured on the basis of the ordinary Geologic Map, which showed the outcrop of the Chalk devoid of Drift, and of any but the large outliers of the Tertiary beds. This is not to be wondered at, there being no other sort of map to go by.

How this acted in a specific case, in Hertfordshire, is well shown by the remarks of the Rev. J. C. Clutterbuck, in his letter to Sir J. Sebright, published in 1841 (pp. 6, 7), criticising the scheme for the proposed supply of London from the Basin of the Colne. "How and where Mr. Stephenson finds '113½ square miles of chalk country which has its drainage into the Ver and Colne, above Watford, divested of any covering which can intercept the passage of the moisture,' I am at a loss to imagine . . . no one acquainted with the condition of the surface of the land, would have printed such a statement."

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[1] *Trans. Herts. Nat. Hist. Soc.* 1899, vol. x, p. 69.

[2] *Journ. Soc. Arts*, 1855, vol. iii, p. 173.

As early as the very middle of the nineteenth century PRESTWICH, whose knowledge of the Chalk and Tertiary tracts was unrivalled, saw the general danger of this over-estimation, and drew attention to it in the following words :—" Over large districts . . . the chalk, however, is not bare, but is covered by an impermeable bed of a ferruginous drift clay [the clay-with-flints], 10 to 20 ft. thick, impeding almost invariably the passage of the surface water into the chalk below."

" It is to be observed also that there are several outliers of Tertiary strata of some extent (omitted generally in the Map) which further reduce the area of bare chalk."[1]

Nevertheless the practice continued, and it was not indeed until the Geological Survey mapped the various beds of the Drift that anything like a proper correction could be made. The first map to be published with the Drift beds coloured on it was Sheet 7, which was issued in 1871, as also was 1, N.W. Other sheets (45, N.E., 46, N.E., S.E., 47) relating to our district followed from 1873 to 1898.

With the publication of these Drift Maps it became possible to get a much more correct idea of the area of Chalk available as a gathering-ground for water, as by them we knew not only of the largeness of the area over which the Chalk was capped by the Clay-with-flints, above alluded to, but also of that where Boulder Clay, generally of greater thickness, occurred over the surface, and altogether hid the Chalk. The Tertiary outliers had, of course, been mapped by the Geological Survey long before.

The value of these Drift maps, in enabling TOPLEY to measure the areas of various formations at the surface, has already been noticed (p. 14); but something more than that is wanted for the purpose of getting at the area of Chalk that acts as a gathering-ground for water : for that we want to know something also as to underground extension of the beds.

The subject came before me some years after the publication of the earliest of the Drift Maps above noted, and I devised a set of " Chalk Area Maps " for the special purpose of showing the extent to which that formation was accessible to water from the surface. These maps are not strictly geologic, and the only point in which they exactly followed the Geologic Maps was in the area of bare Chalk, that is where the Chalk is either at the surface or covered only by ordinary soil. They have been described on various occasions (*see* Bibliography, 1884, 1892); but a description may fairly be given here, as far as regards the two counties.

Passing over the one matter settled by the Geologic Maps, the area of bare Chalk, the chief thing to be settled is the areas where there are permeable beds, and those where there are impermeable beds above the Chalk, without regard to geologic age. Clearly, from this point of view, the great tracts of Boulder Clay and of London Clay have to be coloured as impermeable, and the surface-areas of these formations can at once be so treated. But that is not enough, we have also to consider the underground extent of such impermeable beds, and therefore we cannot altogether accept the areas where permeable beds are mapped as at the surface. For our purpose we can only accept as permeable those tracts where the Chalk is covered by permeable beds

[1] 'The Water-bearing Strata of the Country around London,' 1851, p. 60.

alone, as in the case of the gravels in the valleys, as well as of some of those on the higher grounds. Our impermeable tracts on the other hand must include all where the Chalk is protected by impermeable beds, either at the surface or underground.

Then, however, another trouble occurred. It was soon found impossible to hold to a hard and fast division of permeable and impermeable. We are sometimes faced with a set of beds of an intermediate composition, of such material as will delay, though not altogether prevent, the percolation of water; beds that are neither sands or clays, but varying mixtures. Again, there are formations that vary in character; at one place clay, at another sand, at another half and half, and perhaps at another a mixture: the Reading Beds of our district are an example. The only way to deal with such things was by a method of compromise, the establishment of a group of beds of mixed or varying character, which could be classed either with permeable, or impermeable, or divided between them.

Finally, it was found that the tracts coloured as impermeable could not be wholly condemned, as in large parts of them the rain that falls runs over the clay-slopes so that at last much of it reaches the Chalk; and the impermeable areas had therefore to be divided into those where the drainage did not flow to the Chalk and those where it did, of which there is so good an example in the large clay-tract whose waters go into the Mimms swallow-holes (*see* p. 86).

Having settled on the above-noted five divisions of our Chalk-area, together with the borderland of Tertiary beds that contributes water to the Chalk, it remains to fit the various geologic beds into the scheme.

Beginning with the newest, the Alluvium of the streams, although usually of a clayey character, yet, on account of its thinness, of its being generally more or less soaked with water, and of its sometimes being cut through to underlying gravel, falls into the mixed group.

The Clay-with-flints and its accompanying brickearth are also more safely put in the same group, for, although of a more or less clayey character, their very origin seems to have been, to some extent, at least, brought about by the infiltration of water; and the very irregular way in which they rest on the Chalk can be explained in no other way than by infiltration.

The various gravels and sands of the Drift are probably the most permeable beds we have to deal with, but, where an impermeable bed comes between them and the Chalk, they cannot feed the latter with water. It seems likely, indeed, that more water may get into the Chalk through a gravel than where the former is bare, as rain would sink more rapidly into gravel than into chalk, and would be less liable to loss by evaporation or by growth of plants.

The Boulder Clay as a whole is impermeable. At places there are sometimes slightly permeable layers, but of no great extent, and negligible as far as regards the Chalk. The formation, however, certainly allows a very slow infiltration of water to a certain depth, as is evident from its decalcification, the chalky matter having been dissolved out of it. But this, too, is negligible, as of no effect except where the formation is very thin, that is, generally speaking, near its edge, and would only result in throwing that edge into the mixed group, a matter of practically no account on a map on the scale of an inch to a mile. It

seems likely that in some cases beds belonging to the Glacial Drift and coloured as loam are, to some extent at least, merely decalcified Boulder Clays.

The mass of the London Clay, of course, is impermeable ; but here, again, the very edge is an exception, as the thin basement-bed is generally somewhat sandy ; but its outcrop could not be shown on a one-inch map.

The four groups of areas above described were measured by E. Easton, on the maps available at the time, and the results as to the five sheets with which we are concerned are given in the following table. I have made a very slight reduction in the figures originally given, as the totals added up to a trifle more than the total area of the sheet (where the whole sheet is dealt with), and, therefore, presumably the same has happened in the two sheets in which the whole area is not dealt with, part relating to beds below the Chalk.

Of course in the cases of Sheets 7 and 47 large tracts are included which have no connection with the Chalk-outcrop, and were never included in any estimate of the Chalk-area ; but at present we can only go by the sheets. On the other hand, no division having been made at first between the parts protected by impermeable beds and draining to the Chalk and the parts draining away from the Chalk, the two are here massed together.

When the new Geological Survey has been made it will be possible to renew this work in more detail, to extend it, and to give its results not only by sheets of the map, but also by counties or by river-basins. I can only say that I did my best with the materials at hand, and with the help of various colleagues. I must leave it with my successors to revise and continue it, if that is thought to be worth while.

Group of areas.	Map 7. Partly Bucks. and Herts.	Map 46, N.E. Chiefly Herts.	Map 46. S.W. Chiefly Bucks. and Herts.	Map 46, S.E. Chiefly Herts.	Map 47, Partly Herts.
Bare Chalk	125	74	51	76	103
Chalk covered by Permeable Beds only	88	6	2	38	48
Chalk protected by Mixed Beds...	180	nearly 4	22	66	12
Chalk protected by Impermeable Beds	430	21	nearly 1	26	658

The figures stand for square miles.

Water-level in the Chalk.

There is a long set of papers dealing with or referring to the subject of water-level in the Chalk of Hertfordshire, and the Rev. J. C. Clutterbuck was a pioneer in this matter, with several papers (*see* Bibliography) which deal largely with the probable effect of pumping away water for the supply of London.

In the plate to his Letter to Sir J. Sebright (1841) he gives a section from the Chiltern Hills to the Colne, showing the highest, the lowest, and the mean water-level from Studham on the north to the Bushey

Experimental Well on the south, but without dates, and a map, on the scale of an inch to a mile, marking the sites of the wells observed from Whipsnade Hall on the north to Watford on the south.

In his paper of 1843 he gave a like section, on the plate, showing the difference of the underground water-level in May and October, 1842; and in 1850 (plate) he gave the section, on a larger scale, with February in the place of May, marking the wells measured, and the level of the Gade. This section is again repeated, on the smaller scale, in his paper of 1864, in which it is described as along the ridge between the Gade and the Ver.

Several years later the Rev. J. C. Clutterbuck said :—[1]

"It has been calculated that after the summer months, when generally there is no percolation of water to the subterranean reservoir (of the Chalk), it requires at least three inches of continuous rainfall to replace the evaporation from the soil. When the soil is saturated, a considerable per-centage sinks into the earth and an accumulation of water takes place; and as the water moves, by natural gravitation, towards its vent or outfall—the rivers which run in the lowest valleys—in its passage thither it encounters a resistance which so retards its progress that it assumes an inclined surface, which is the balance between this resistance in the medium in which the water flows, and the hydrostatic force by which its progress towards its vent is quickened. This inclination of surface varies with the presence or absence of cracks, fissures, and orifices, through which alone the water in the Chalk can flow. The distance from the outfall regulates the amount of storage in the subterranean reservoir in the Chalk. The whole average inclination of the surface of the water, from the Chiltern Hills to the Colne, is 13 ft. in the mile. Besides this which may be called the longitudinal, there is a lateral adjustment of inclination of surface rising from the river on either side to the centre between two rivers, flowing in parallel line towards the south." He gives examples from Watford and says :—"At one time the Chalk under Watford was perforated with wells; they are now (1876) mostly, if not all, filled up, but the measurements of the varying level of the waters have been retained," which is a piece of good luck.

J. Lucas has given statistics of the levels and of the water-levels of wells in the Chalk in the valley of the Colne and southward from Hitchin.[2]

Sir J. Evans has written of the Chalk-tract of Hertfordshire[3] "that it is intersected by valleys . . . , and that along the bottom of these there is a constant outflow of water from springs either along the beds of the stream or at their sides. By means of these the volume of the streams keeps gradually increasing as they flow; and as they are . . . nearly independent of any immediate rainfall, it is evident that they are supplied from underground sources, and in fact are draining a subterranean reservoir of water among the crevices and interstices of the chalk . . . the upper surface of this reservoir" is "the plane of saturation, though it is not properly speaking a plane, but an uneven surface presenting valleys and elevations closely allied

[1] *Trans. Watford Nat. Hist. Soc.* 1876, vol. i, p. 129.
[2] *Trans. Inst. Surv.* 1878, vol. x, pt. xi, p. 279, tables iii, iv.
[3] *Proc. Inst. Civ. Eng.*, 1885.

to the surface of the ground above it, though, so far as elevations are concerned, much less in degree. The extent to which friction impedes the passage of water through pervious rocks varies considerably even in chalk. It must, however, in all cases be sufficient to retain the underground water at a slope fully as great as that of the streams running on the surfaces. In the middle chalk in Hertfordshire this slope is about 12 ft. 6 in. to the mile, and nearer the outcrop in the lower portion of the white chalk about 19 ft. 6 in." I gather, from a paper of 1877 (*see* p. 339) that the word "outcrop" is here, by mistake, used for the lower boundary of the Chalk, as the high grade is certainly in that direction, and that "middle" is not used for what we should now class as Middle Chalk, but simply for the middle part of the Chalk-tract. "It is evident that could the water find its way along underground with a less head than say 12 ft. 6 in. to the mile, it would do so, and the stream would disappear. We can therefore assume that even in comparatively dry seasons the plane of saturation may be regarded as presenting much the same contours as the country itself would present were the hills planed away until their slope presented uniform gradients of about 13 ft. to the mile. After heavy rainfalls, however, the water descending through the soil and arriving at this plane would gradually be piled up until the slope might be two or three times as much as this 13 ft. to the mile; and in dry seasons the water thus piled up would by force of gravity again subside and be delivered into the outlets along the bottoms of the valleys. The spring-heads or sources of the streams would, owing to the accumulation of water from heavy rainfalls, be gradually driven higher up towards the heads of the valleys, so that the length of the streams might be increased by some miles."

"Of course the inclination of the plane (of saturation) towards the bottom of the valleys in which the water escapes is constantly varying. If the rainfall which finds its way into the ground is in excess of the water escaping by the springs, the angle of the plane becomes greater. If, on the contrary, the escape by the springs is greater than the absorbed rain, the angle is reduced. It is this circumstance which accounts for the intermittent streams which are commonly known as 'bournes.' These are usually situated in transverse valleys, running into some main valley in which there is a stream." When the plane of saturation is at a less gradient than the inclination of the transverse valley there will be no water at the surface; but when the reverse is the case the bottom of the valley cuts the saturation-plane and a stream results. "When the bottom of the valley is uneven, and the slope of the plane of saturation nearly corresponds with the mean of that of the valley, the phenomenon is seen of a watercourse running at intervals."

"Although the whole of the chalk below the plane of saturation is full of water, and more or less pervious in every direction, yet as the surface of the plane descends, the water, in escaping into the valleys, follows certain lines of least resistance, and thus in many places gives rise to springs sometimes of great volume."

"In the upper portions of the chalk there are usually layers of nodules of flint, extending over large areas and occurring at intervals of 3 or 4 ft. . . . Among these flints the underground water seems often to find its way more readily than through the interstices and crevices in the chalk itself; so that, in boring, an accession of

water is obtained directly a layer of flint is traversed. So readily do these waterways communicate with the stores of water at a higher level, that the water in a deep boring in the bottom of a valley will rise higher than the level of the stream . . . and overflow."

I believe, however, that the more or less vertical slight fissures along the joint-planes are more effective than the layers of flints, and they are present when there are few or no flints.

With regard to the effect of swallow-holes, down which water flows into the Chalk (*see* p. 62) Sir J. Evans says, "it seems probable that by the continual delivery of large bodies of water into one place the lines of least resistance in the chalk have been widened out by combined mechanical and chemical action, so that subterranean watercourses are formed."

J. Hopkinson has remarked[1] that the water that percolates into the Chalk "descends to the plane of saturation with very varying . . . rapidity; where the chalk is compact, the percolation is exceedingly slow; where it is fissured or there are 'pipes' filled with loose gravel . . . it may be very rapid. In our Upper Chalk district the water on its way down encounters nearly horizontal bands of flints loosely aggregated together, along which it flows much more readily than in the compact chalk. It will therefore tend to flow along the plane of dip . . . which, in the valleys of the Lea and Colne, is from north-west to south-east at a slight angle."

Prof. Attfield said in a discussion in 1890[2] that he had recorded the water-levels in his well (at Watford, northern part) for six years, with the result that "in 1884, the difference in the height about February, when the water attains its maximum, and in November or December when it attains its minimum, was 3·6 feet in 1885, 2·6; in 1886, 3·5; in 1887, 5·1; in 1888, 3·4; in 1889, 2·9; Therefore, as far as his well represented the wells in the neighbourhood, Watford might rest content that there had been no very great draw on the water." And he thought that the big wells were not interfering with private wells.

In summer the rain does not get down to the water in the well. "In January or February, however, with the amount of rain that has fallen during the earlier part of the winter, the whole of the soil down to the plane of saturation becomes wet, and a heavy rainfall will make itself felt in the course of two or three hours."

Dr. Brett said "that observations made by Mr. George Wailes at the London Orphan Asylum showed nearly the same results as those stated by Professor Attfield."

In a discussion at Watford, on the lowering of the (underground) water-level,[3] J. Hopkinson said:—"In the Lea district . . . the rainfall was not so great as in the Colne district, yet much more water was taken from that district for the supply of London than was taken by the Colne Valley Water Company and from other deep wells in the neighbourhood of Watford; therefore, they might expect that the water in the Lea district would be lowered more than the water here. There the New River Company was evidently taking more than could be spared, which was gradually lowering the water-level in the Chalk. Fifty

[1] *Trans. Hert. Nat. Hist. Soc.*, vol. vi, p. 145.
[2] *Ibid.*, 1892, vol. vi, pt. 7, pp. xxiii, xxiv.
[3] *Ibid.*, pp. xxix–xli.

years ago no one ever heard of deep wells running dry; now, with a considerably greater rainfall, the water level was getting low, and there seemed a probability, if the draw upon our underground resources continued to increase, that we should be short of water ourselves."

F. M. Campbell said:—"His own well at Hoddesdon was now pumped dry every day, and his neighbour's wells were pretty nearly in the same position, in fact every well which was not exceptionally deep."

J. Hopkinson added "that the level of the water in our Chalk rivers, when flowing immediately on the Chalk without the intervention of any impervious bed, was the level of the underground water in the Chalk, therefore if the underground level be reduced, the level of the river will be reduced, and our Chalk rivers in course of time will cease to flow in dry seasons. Some years ago it was found that the volume of the water in the Ver was decreasing. For the sake of the mills, several borings were made in the neighbourhood of Redbourn, and from them a large amount of water was obtained. But the water which flowed from these borings would have gone into the river in springs; therefore all that trouble and expense might have been spared."

Very many cases of the lowering of water-level are given in U. A. Smith's "Statement" to the Royal Commission on Metropolitan Water Supply of 1893 (Appendices). But these include not only some that are owing to extensive pumping from wells, but also many that cannot be traced to such a cause, being at places far away from any pumping, and to be explained by that universal seasonal variation to which we owe intermittent streams: some of them indeed are cases of bourne-flow. Many of the figures are repeated in this Memoir under various headings, where they are very useful; but it is out of the question to reproduce all, for the above reason and to avoid controversy. It is to be wished that such a record should be extended and systematically continued.

Throughout R. E. Middleton's lengthy Report to the Royal Commission on Metropolitan Water Supply[1] there is much information on the subject of water-levels in many wells, and about four pages are devoted to a tabular statement, chiefly for Hertfordshire.

He also produced a Water Contour Map of Hertfordshire,[2] on which were shown the underground water-contours for every 50 ft., from 50 in the valley of the Lea to 400 on the high ground around Dunstable and Kensworth, with the sites of the wells on which the lines are based and the water-levels at those wells. The limits of the Watershed, both above and below ground, are also shown and the direction of underground waterflow. The scale of this map being an inch to a mile its information can be readily applied to the Ordnance Map on the same scale. Probably, however, there is now a good deal more information to be had on these matters.

On p. 641 of the *Appendices* to the Report of the Commission he says, "where the escarpment of the chalk towards the north is sharp, the underground watershed is to the south of the surface boundary of the Lea basin, and is therefore within it . . ., while on the west side (of

[1] *Appendices*, 1893, pp. 540, etc., especially 641–645.
[2] *R. Comm. Metrop. Water Supply, Maps, etc.*, 1893, Pl. xv.

the Lea basin), where the escarpment towards the River Lea is steep, and the slope towards the River Ver is, comparatively speaking, flat, and the River Ver itself runs at a higher level than does the River Lea, the boundary of the underground watershed is to the westward of that which appears on the surface, and is outside of the surface watershed."

"The general effect of the observations, so far as they have been conducted, is to slightly increase the area of the underground watershed of the River Lea over that which is found on the surface . . ."

"The headwaters of the Ver, not only above, but below Kensworth Lynch, are found to drain (underground) to the Lea Valley."

Middleton also issued a "Water Contour Map of Parts of Herts. Cambs. and the Adjacent Counties," which is for the most part the same as that noticed above; but does not cover the ground so far to the west, whilst, on the other hand, it extends further on the east, to Saffron Walden and Bishop's Stortford. It is undated, but gives water-levels in 1893, 1897, and 1900, so that it is some years later.

Some remarks made by J. Hopkinson in 1896 are noticed further on (pp. 106, 107).

In 1897 Harold Warren published a paper on "Water-levels in the Chalk near Royston"[1] (based on records from wells and springs), and dealing with the north-eastern part of Hertfordshire and the adjoining part of Cambridgeshire. "This being a bare chalk area, the plane of saturation almost invariably rises beneath high ground, the springs below increasing or decreasing according to the hydrostatic pressure behind them. . . . The variation of level due to rainfall is, of course, felt in the wells on the higher grounds more than in the shallower wells," in the lower grounds.

"The wells in which these water-levels were taken all derive their water-supply from the Middle and Lower Chalk," only two going through a few feet of Upper Chalk, and the springs, at the foot of the escarpment are from the Totternhoe Stone, the top of the Chalk Marl.

The levels, with few exceptions, "were taken between the 30th of December, 1895, and 10th January, 1896, at about which time the winter rise of level usually commences in this area."

He gives a map with the sites of wells observed, and with "the subterranean contour of saturation where it is 145 ft. above Ordnance Datum." This curved line reaches from Ashwell, by Therfield Heath, and by just south of Royston to Whiteley Hill, south-east of that town.

There are also four sections: 1. Along the line of springs from Ashwell east-north-eastward, by Litlington, Bassingbourn, Kneesworth, Melbourn, to Shepreth (so-called, but really in the parish of Melbourn), and therefore almost wholly in Cambridgeshire, showing an easterly fall in the water-level from 145 to nearly 72 ft. above Ordnance Datum, "a fall of 74 ft., giving an average gradient of nearly 5 ft. per mile." 2. From the Hare and Hounds, east-north-eastward by Odsey Grange, the Thrift (on the parish boundary of Therfield), Royston Waterworks and Heath Farm (in the parish of Melbourn) to the Coach and Horses (in the parish of Great Chishall), also showing an easterly fall in the water-level, from 192 to 88 ft. above Ordnance Datum. To Royston this is practically along the county-boundary.

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. ix, pt. vi, pp. 209–214.

Beyond that town it passes into Cambridgeshire. 3. Across the outcrop of the beds from Therfield Rectory north-north-westward to Litlington Spring, half in Hertfordshire and half in Cambridgeshire. This, of course, shows a northerly fall in the water-level, and at a greater angle than the preceding sections, from 284 to 105 ft. above Ordnance Datum, in a shorter distance than the others, "a fall of 179 ft., giving an average gradient of 45 ft. per mile." The water-levels along this line of section were taken in March, 1897. 4. is obliquely across the outcrop of the beds, from Therfield Rectory north-north-eastward through Royston to Melbourn spring, in Hertfordshire and Cambridgeshire, and also shows a northerly fall in the water-level, in a downward curve from over 253 ft. to nearly 77 ft. above Ordnance Datum, "a fall of 177 ft. and a gradient of 35½ ft. per mile."

There is a table of the wells observed, with their measurements.

In 1898 I made some remarks on the subject of the underground water-level in the Chalk of Hertfordshire, the substance of some of which may fairly be repeated.[1]

As a general rule the underground water-slopes in the Chalk show a rough parallelism with the contour of the ground: as the ground rises the underground water-level rises too, though to a much less extent; but sometimes (? often) the summit of the water-slope is not under the summit of the ground-slope, the water-hill and the ground-hill being in different places. Sometimes, indeed, the water-slope revolts, asserts its independence, and seems not to be governed by the ground-slope.

A case of the sort occurs in Hertfordshire, and for the facts I am indebted to U. A. Smith, the late County Surveyor. In a section plotted across the valleys of the Rib and of the Lea from north-west to south-east, to show the levels of water in wells, etc., the following figures came out, all referring to feet above Ordnance Datum:—

	N.W.	River Rib.					River Lea.	by Chadwell Spring.	
Ground-level ...	275	165	138	233	244	222	194	110	152	227
Water-level ...	167	141	138	128	128	113	112	110	108	107

The gradient of the water is 26 ft. in a mile from the first well observed to the Rib, and beyond to the next well; then 9 ft. (? some error) to the next, a little way off; then 29 ft. to the next; 12 to the next, a little way, and then 11 ft. to beyond the Lea.

Now, whilst the ground-level of course shows a set of rises and sinkings there is a steady fall in the water-level south-eastward, without any rise under the higher ground between the Rib and the Lea, over a distance of about 1⅝ miles.

The explanation that occurred to me was naturally a geologic one, and I give it for what it may be worth. In the district in question bare Chalk occurs only at the basal part of the valley-slopes, the whole of the rising ground between these narrow outcrops being composed of Glacial Drift (largely Boulder Clay and loam). The rain therefore is greatly, or in places perhaps wholly, hindered from getting into the Chalk on this higher ground, and so there is little local addition

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. x, pp. 8–10.

to the water in the Chalk, and no cause for local rise in the water-level. Moreover, from the thickness of the Drift the Chalk itself cannot rise much under the hill. The water-slope in the Chalk is left with little interference from above, and so follows the general dip of the beds or, the *general* slope of the ground (without regard to local variations) both more or less from north-west to south-east, as perhaps also is the general direction of the main fissures or joint-planes in the Chalk.

In the 18 years since the notice of the above was printed no other explanation has been put forward; but I am still ready to accept a better one.

Character of Chalk Waters.

One of the most notable characteristics of Chalk-water, that is to say, of water got from the Chalk where that formation is at or near the surface, is its hardness, given to it, as with other limestone-waters, by the amount of calcium-carbonate that is taken up during the passage of water through the rock.

Two papers devoted to this subject, as regards Watford, give one a text for a short discourse thereon. Both were published in 1895.

The first, by J. Hopkinson, is cautiously entitled, "The Relative Advantages of Hard and Soft Water";[1] and begins thus: "The question . . . is a very wide one. Considered in an economic light it cannot be denied that the advantages are decidedly in favour of soft water; considered from a sanitary point of view, it must first be resolved into two distinct questions," of external and internal use. In the matters of washing ourselves and our clothes and of cooking he decides in favour of soft water, "and the only sanitary question which is really open to debate is whether soft water or hard water is best for us to drink." The various points of this debatable question are fully and fairly gone into (with a soft bias), and the moral seems to be that it would pay to soften the water supplied to Watford as I believe has been done lately.

The second paper follows on, and Dr. A. King more boldly entitles it, "On the Advantages of a Supply of Soft Water,"[2] of course therefore being uncompromising against hard water.

Whilst generally disposed to advocate the softening of Chalk-water, for general use, especially as that process is also a purifying one, I cannot accept the arguments that have often been brought forward in regard to the effect of hard and soft waters on the general health of the consumers. Those arguments have been largely based on the comparison of districts that are far apart, and in which therefore various other circumstances, natural and artificial, interfere to a large extent. Moreover, in many cases there are factors other than a change in water-supply which have acted powerfully in improving the general health of a community.

To get a proper comparison of the effects of hard and soft water on health, it is essential to deal with districts of large size and population, near to one another, and, generally speaking, under like circumstances; so that other matters than that of water-supply may be safely neglected. This has been done by Dr. J. C. Thresh, dealing with the large county of Essex, so much of the water-supply of which comes from wells sunk

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. viii, pt. 5, pp. 101–115.
[2] *Ibid.*, pp. 116–124.

into the Chalk[1]. The substance of his work has been given in the Memoir on the Water Supply of Essex (pp. 67—69).

He divided the district treated of into Soft Water Areas, Moderately Hard Water Areas, and Hard Water Areas, all with large populations, and with water-supplies of admittedly good quality. The result, expressed in death-rates, is practically a tie: in the first year Soft Water was the lowest with 10, Hard Water (two groups) having 11·1 and 11·2, and Moderately Hard (two groups) 11·2 and 11·5; but in the second year the figures were somewhat reversed, Soft 10, Hard 10·6 and 9·9, Moderate 9·9 and 10·9. "These differences are so slight that only one conclusion can be deduced, namely, that the character of the water supplies in the county (as to hardness) had no effect upon the death rates."

Despite all that has been said as to the advantages of soft water, as far as I know in only three large supplies in Hertfordshire, those of the Chiltern Hills Company of the Colne Valley Company and of Watford, has a softening process been adopted, and in none in Buckinghamshire.

An elaborate paper on Well Waters by R. Warington is of great general interest, though almost wholly concerned with part of Hertfordshire, and the heading, "The Well Waters of Harpenden," covers more than 20 pages and 3 charts.[2] Eleven years later I expressed my sense of the great value of this essay and quoted from it;[3] but now a more extended use of it will be made.

The author deals first with the Rain Water, especially as regards its amount of chlorine of sulphuric anhydride and of ammonia (pp. 500-503), and then treats of the Drainage Waters (pp. 504-520), before coming to the matters which are here of special interest.

He begins thus: "The well waters of which I have to speak occur in or near the village of Harpenden, and within a short distance of the rain- and drain-gauges . . . at Rothamsted. . . . The soil in the valley is more or less gravelly; on the hills, on each side, the surface soil is clay mixed with flints. Below the surface soil comes in every case the chalk; this is in some places quite near the surface, and in other cases as much as 25 ft. below. All the wells are sunk into the chalk."

"The height of the water in the wells is, of course, subject to variation at different times of the year, but it may be generally stated that in the centre of the village (low ground) the water level is rather less than 60 ft. below the surface. The extreme depth is reached . . . on the high ground on the east of the valley (one well); the water level is here about 145 ft. below the surface."

"In the valley the water-level in the wells is about 290 ft. above the sea level. In the wells on the high ground to the west . . . the water level is distinctly higher; while . . . on the east hill (one well) the water level is distinctly lower than in the valley (not what one would expect). There is thus a steep gradient in the water level from north to south . . . and also in the direction of west to east. The existence of these steep gradients will, of course, determine a steady flow of the underground water in the directions indicated. This fact

[1] 'County of Essex. Report of the Medical Officer for 1910,' pp. 138–142. *Ibid.* for 1912, pp. 27–35.

[2] *Journ. Chem. Soc.*, 1887, vol. li, pp. 500–552.

[3] *Trans. Herts. Nat. Hist. Soc.*, 1898, vol. x, pp. 12, 13.

is one of primary importance, and must be borne in mind when we have to study the alterations in the composition of the well waters."

"The waters of about 30 wells, in or near the village of Harpenden, have been examined, and a few others from the neighbourhood." The author's main object was "to inquire what are the facts which the varying quantities of chlorides and nitrates indicate."

"The examination of well waters . . . was commenced . . . simply with the object of satisfying individual householders as to whether their well was contaminated by sewage. As results accumulated, it was found that the composition of many well waters varied considerably at different seasons of the year. Certain wells were then selected for systematic examination, and determinations of the chlorine and nitric acid in their waters were made every month. . . . The systematic examination . . . has been continued during two years."

"The constant supply of water to the deep wells of Harpenden is derived from the drainage of a district to the north-west of the village, and is thus independent of the local drainage. . . . This constant underground supply of water to deep wells, being the result of percolation over a wide area, and through a great depth of soil, we should expect to have a constant composition throughout the year."

"Besides the main water supply . . . there will in nearly every case be more or less of local drainage. . . . If this local drainage percolates through a very considerable depth of soil before entering the well, it will supply a water of nearly constant composition. . . . If, however, as must frequently be the case, the local drainage finds access to the well not far below the surface, or through deeper channels coming directly from the surface, the composition . . . will be different at different seasons."

He then discusses the waters under the heads Generally Uncontaminated and Generally Contaminated, with the tables referring to 6 of the former and 9 of the latter (but without sites being given), recording the amounts of chlorine and of nitrogen as nitrates over a long series of months.

"There is abundant evidence that the normal proportion of chlorine in the pure well waters of the Harpenden district is about 11 per million."

"We may adopt 4·7 per million as the average amount of nitric nitrogen in the pure well waters."

"The proportion of nitrates is not, as in the case with the chlorides, perfectly constant throughout the year in the waters of all uncontaminated wells."

Of the contaminated wells he says, "The waters in these wells are held to be contaminated because the proportion of chlorides and nitrates which they contain is generally considerably above that belonging to the purest well waters of the neighbourhood, and we may consequently conclude that they are polluted by the products of the oxidation of sewage present in the surrounding soil"; but as to their wholesomeness he says "that during the time of the current investigation they were drunk apparently with impunity," and he gives instances of wells, the surroundings of which are bad, but the water of which nevertheless reaches a fair degree of purity.

He aptly remarks, "Wells are generally ill-provided with any protection to prevent soakage through their walls. The old wells of Harpenden are steined with flint, laid on hard mortar or cement, and

this steining is often carried to a considerable depth. This plan appears far better than the modern one of steining with loose brick, without any cementing material."

"The amount of water taken from a well must largely influence its apparent degree of contamination. The local contaminated drainage is strictly limited in quantity, the underground supply of pure water is practically unlimited in amount; by continuous pumping the proportion of impurity in the water may thus be greatly diminished."

"The proportion of chlorine in the contaminated well waters varies of course immensely in different wells . . . sometimes as low as 11 per million . . . in the case of one well as high as 173 per million. The marked characteristic of the chlorides in a well water receiving fresh contamination is that they are a *variable quantity* at different seasons; while the amount of chlorides in a well water not suffering from new contaminations of sewage is practically constant. It follows that the ascertained purity of a well water at one season of the year may be no proof of its general freedom from sewage contamination."

In the wells examined the "dates of minimum chlorine occurred at the end of a period of dry weather . . . The local drainage through the soil having thus ceased, or been reduced to a minimum, fresh contamination by the percolation of sewage was suspended, and the supply of water to the wells being thus limited to the flow of pure underground water, the chlorides and nitrates were reduced nearly to the proportion found in uncontaminated well waters, save in cases where probably the soil had become saturated to a great depth with sewage products."

Apparently "new pollution set in before the water level in the wells began to rise. . . . These facts illustrate the independence of the source of pollution fron the main water supply . . . the latter is derived from a large drainage area, while the source of pollution is purely local. The chlorides and nitrates of local drainage are probably in most cases discharged into the well at no great distance from the surface. . ."

"The relative proportion of nitrates and chlorides is by no means the same in all the well waters; some have a decidedly chlorinous, and others a decidedly nitric, character."

The difference between the mineral contents of the two classes of water is well shown by the following table, the figures being parts per million.

	Uncontaminated.	Contaminated.	
Lime	158·	211·	220·
Magnesia	4·1	9·7	10·5
Sulphuric anhydride	3·8	28·5	15·8
Nitric anhydride	18·9	82·2	74·4
Carbonic anhydride	118·7	130·6	124·2
Chlorine	10·7	32·7	71·
Silica	17·6	15·8	15·4
Undetermined	15·8	49·5	68·1
Total solids	347·6	560·	599·4

The degrees of hardness were 20·5, 28·1 and 29·3.

Two of the constituents, "silica and carbonic acid, are in nearly the same amount, whether the water is contaminated or pure. The lime and magnesia . . . show a considerable increase in the contaminated waters; and as this increase is without any corresponding increase in the carbonic acid, it is clear that these bases are here combined with nitric, sulphuric, or hydrochloric acid, thus considerably increasing the permanent hardness . . . nitrification in a soil results in a solution of the bases, chiefly lime, by the nitric acid formed; we have here the results of this action. The proportion of magnesia to lime in the pure water is 1:39; in the *excess* present in the contaminated waters it is rather more than 1:10. The undetermined matter (partly combined water) undoubtedly contained alkalis, as the acids are in every case in excess of the bases determined. The alkalis, on these grounds, must have been between three and four times as much in the contaminated waters as in the uncontaminated. . . ."

"The water of the uncontaminated well contains a mere trace of of sulphuric acid," and a second and more accurate determination reduced the figure to 2·75 per million, an amount "hardly greater than that found in the rain at Rothamsted. . . In the contaminated waters the amount of sulphuric acid is very considerably increased," and the difference between the two wells, not far apart, is accounted for by the sewage from one being "derived from a much better fed population" than that of the other.

Perhaps the most interesting part of WARINGTON's paper is at the end, in the Comparison with Results from other Wells, referring as it does to larger areas and bearing on the marked differences in the water got from the Chalk where that formation is at or near the surface and that got where the Chalk is thickly covered by Tertiary beds.

In the Sixth Report of the Rivers Pollution Commission SIR E. FRANKLAND recorded a great number of analyses of Chalk-waters. "Of these, 30 springs, and 65 wells, are classed as 'unpolluted,'" and these compare perfectly with the Harpenden waters.

"On looking at this valuable series of analyses, one is struck by the fact that the minimum of chlorine observed in the Harpenden well waters hardly ever occurs. Out of 111 samples of water there are only 2 containing less than 11 per million of chlorine. . ."

"As many of the springs and wells examined were of the highest class, it would appear that there is some peculiarity in the chalk water of Harpenden, so far as its contents in chlorides is concerned. I venture to think that the low proportion of chlorides in the pure well waters of Harpenden may be due to the situation of the village not far from the escarpment of the chalk. . . . The chalk here being at a considerable elevation . . . . and the gradient of the underground water level very considerable, the chalk rock has been in the course of ages washed very thoroughly by the percolation of rain, and the chlorides originally present in the rock when upheaved from the sea have been almost completely removed. The wells in the lower part of the chalk basin are obviously supplied to a considerable extent by the underground drainage from the upper part of the basin. This underground drainage water when it passes Harpenden contains about 11 of chlorine per million of water; but as it continues to percolate

through masses of chalk at a great distance from the surface, it may be assumed to gain chlorides from the small residue of common-salt remaining in the rock; so that wells in the lower part of the basin should, on an average, contain water richer in chlorides than wells at the edge of the basin."

Warington confesses his inability "to prove that the well waters of the chalk basin become, on an average, more chlorinous as they approach the centre of the basin."

He continues, however, thus:—"Direct evidence as to the presence of common salt in the chalk seems to be furnished by the general considerable excess of chlorides in uncontaminated well waters over the amount furnished by rain. . . . Still stronger evidence is supplied by the condition of the well waters in the chalk when this formation is covered by the London clay. The clay has of course prevented any percolation of rain from above; the washing of this chalk has therefore for many ages been confined to the slow passage through it of water from the upper part of the basin, already containing chlorides. Under these circumstances we find a well water extremely rich in chlorides. . . . This richness in chlorides occurs in wells now far removed from the sea."

Since the publication of Warington's valuable and suggestive paper further evidence of the changes in character of Chalk-waters underneath Tertiary beds has accumulated. In the same year (1887) there appeared a paper by R. R. Hayward, "On the Water in the Chalk beneath the London Clay,"[1] from which I gave extracts in a Geological Survey Memoir two years later. Unfortunately, however, I did not see Warington's paper until after that Memoir was written, and so gave a feebler explanation of the difference in the waters, suggesting, with some doubt, that "from communication between the Chalk and the overlying Tertiary sands, the water in the former has become charged with some of the saline constituents of those sands, whether original, or produced by chemical alterations going on at great depths, where the beds are saturated with water."[2] There is ground for holding to this as a partial explanation; but it does not seem enough to account for all the facts, as was noticed in my Address of 1898, in which Warington's view was accepted, and the whole matter thus summed up: "The washing out of the salts from the Chalk from the escarpment downward to the central parts of the basin, where concentration would take place; the possible addition there of salts derived from the Tertiary sands . . . and, perhaps, some chemical changes slowly brought about in the deep-seated water: these would seem to be enough to account for the great differences in the mineral contents of waters in the open and in the covered Chalk."

Since then the subject has been gone into in some detail, in the Memoir on the Water Supply of Essex (pp. 15, 16, 19-35), in which Dr. Thresh gives an account of his experimental work, to which the reader is referred.

[1] *Middlesex Nat. Hist. Soc.*, pp. 48–53.

[2] 'The Geology of London,' etc., vol. i, p. 515 (1889).

UPPER GREENSAND.

The Upper Greensand of Buckinghamshire consists essentially of green sand overlying calcareous sandstone with marly bands, the whole nowhere of any great thickness, and thinning out near the boundary with Hertfordshire, in which latter county the Upper Greensand, so far as the surface is concerned, is practically absent. Naturally the outcrop is rather narrow, being never a mile in breadth ; therefore, though the beds are permeable; they cannot give any large supply, and are available only for small local needs.

It is interesting, that notwithstanding its small thickness, and its north-easterly thinning out at the base of the Chalk-hills, this formation seems to extend underground from its outcrop through Buckinghamshire, having been found in the deep boring at Winkfield, in Berks, and more lately in that at Slough (*see* p. 158). It occurs, too, underground in Hertfordshire, having been found in the deep borings at Cheshunt and Ware (*see* pp. 203, 257). These occurrences, however, are of no value in regard to water.

LOWER GREENSAND.

Along its northerly outcrop, from beneath the Gault, this formation is essentially a sand, partly of a more or less ferruginous character, partly light-coloured. But that outcrop in Buckinghamshire is most irregular and patchy, except at the far east, where it forms part of the large Bedfordshire tract. Besides this we have only small outcrops and a set of small outliers, westward of Aylesbury.

In Hertfordshire there is no outcrop ; but there is evidence of underground occurrence at Hitchin, Long Marston and Tring (*see* pp. 222, 232, 254). How far southward this underground extension goes is an unsolved problem ; but it does not reach as far as Ware, the formation apparently thinning out fairly soon in its southerly course underground.

The only notable supplies in Buckinghamshire from the Lower Greensand by wells at its outcrop are those at Linslade, for that place and for Wing ; but the success of the deep boring at Slough (p. 158) is remarkable, and that boring proves a considerable underground extension within the county. There are, moreover, many borings through Chalk Marl and Gault, or the latter only, into Lower Greensand, which have given a supply. On the whole, however, the Lower Greensand, does not count for much in the water-supply of the two counties.

PORTLAND BEDS.

In Buckinghamshire this formation consists of limestone, with occasional thin layers of marl or clay, and sand, with stone ; but the division between the two parts is sometimes vague. They are nowhere of great thickness, and the outcrops are rarely a mile broad.

The Portland Beds crop out from beneath Lower Greensand or Gault from the neighbourhood of Haddenham, where only is there a broad outcrop north-eastward to Bierton, beyond which the Gault passes over on to the Kimeridge Clay (the whole much hidden by Drift), except for a small outcrop of the Portland Beds in the valleys between Cublington and Wing, and for a very small one south of Stewkley.

There are, however, many outliers from westward to northward of Aylesbury, which, often with cappings of Purbeck Beds and of Lower Greensand, form well-marked hills, and are also notable for a number of springs, thrown out by the underlying Kimmeridge Clay, including therewith any of the Hartwell Clay, now classed as Portland.

Nevertheless, there is no notable public supply got from these beds; but many of the villages must have a number of private wells in them.

Great Oolite series.

Though with a broad outcrop these beds are mostly hidden by Drift, chiefly Boulder Clay, which of course greatly detracts from their value as a gathering ground for water. Moreover they are of no great thickness in Buckinghamshire. In Hertfordshire there is no record of their occurrence.

The uppermost division, the *Cornbrash*, is a limestone, but everywhere thin, and never yielding anything but small local supplies.

The *Forest Marble* is not shown on the map, but a thin set of beds has been classed with it. These consist partly of clay and partly of limestone, and seem to belong to the division elsewhere known as the *Great Oolite Clay*, which is practically an equivalent in age, as in position. The effect of these clayey beds is, of course, to cut off the water of the Cornbrash from the beds beneath.

The *Great Oolite Limestone* is the only part of the Series that yields water to a large extent; but this division is often comparatively thin, and contains occasional layers of marl or clay, which interfere with the circulation of water.

The *Northampton Sand*, as its name implies, is largely of a sandy nature, whether in the form of calcareous sandstone, sandy limestone, or sand, and is generally permeable to water; but there is no large outcrop in Buckinghamshire.

The only public town-supplies, from wells in the Lower Oolites, are those of Buckingham (at Maids Moreton, where the Northampton Beds and the Marlstone are also passed through), of Newport Pagnell and of Stony Stratford (the wells also passing through Northampton Beds and Marlstone).

Of formations below the Great Oolite some examples of borings for public supply which reach through to such have just been noted. There is but one town in which the water comes wholly from beds below the Oolites, that is Wolverton, where a supply is given by the London and North-Western Railway Co. from a boring that passes through the Middle Lias, the lowest formation from which water is got in our district.

SPRINGS.

GENERAL REMARKS.

When underground water comes to the surface naturally the result is a spring, when the passage from underground to overground water takes place at a definite spot, or set of spots. Where such passage occurs as a sort of weeping along a line, without starting at defined spots, and forming streams, the American geologists have applied the term seepage to it. This seepage may occur wherever a permeable bed is underlain fairly evenly by an impermeable one ; but springs may occur in other ways also : they may even be at the top of a permeable bed, where that top is at a very low level, at or just below, where impermeable beds come on above. Springs, in fact, arise wherever the plane of saturation in a permeable bed reaches the surface, whether permanently or temporarily. Their position is, of course, often determined by some occurrence which facilitates the outflow of water at one spot rather than at another, such as a more or less open joint-plane in a limestone or other rock, or a specially porous character of the beds.

In one of our counties, Buckinghamshire, there is a dearth of records of springs, and this goes with a like defect as regards the older formations of the district ; indeed, it is not until we come up to the Chalk that we have a good record of springs, and the result is that this heading is almost wholly concerned with the Chalk and mainly with Hertfordshire.

I have found few records of springs (other than what are called mineral springs) in formations older than the Upper Oolites, the only published ones being such notes as occur on the six-inch maps of Buckinghamshire. The few of these that I have will be given merely as specimens, in the hope that they may lead to a fuller account.

LOWER OOLITES.

At Cold Brayfield, rather more than three quarters of a mile north-north-east from the church, Mother Redcap's Spring is marked on the map (Bucks 2, S.E.), and it must rise from Great Oolite limestone.

At Gayhurst four springs are marked on the map (Bucks 5, S.W.). 1, somewhat indefinite, but 725 yards or more east of north of the church. 2, north of Park Farm, and about 610 yards north-eastward of the church. 3, about 740 yards a little north of east from the church. 4, by Mill Cottages, close to the Ouse, south-eastward of the church. Mr. G. A. Branford tells me that No. 2 supplies the village ; that No. 4, now known as Gayhurst Cottages, was thought of for an additional supply to Newport Pagnell in 1907 (but the scheme was abandoned), and the yield was gauged in May of that year at 17,280 gallons in 24 hours. He adds that there is a spring in a spinney, east of the private road leading from the main road to Gayhurst House, which discharges into a well between the two ponds and supplies the house ; and that another spring, in Digby's Walk, comes from ironstone, and its water is used for bathing the eyes.

At Lathbury three springs are marked (Bucks 5, S.W.) :—1, in the north-western corner of the parish, about 325 yards west of south from

Tyringham Lodges; 2, about 270 yards north-north-west of the church; 3, about 800 yards north of north-east from the church. These two apparently come through Drift gravel.

In August, 1889, Mr. Topley recorded a spring at Maids Moreton Mill, on the Ouse, with a temperature of 53°, whilst that of the canal just below was 60°. The water presumably comes from Great Oolite limestone.

At Newport Pagnell there is a spring by a small old quarry about 330 yards east of north of the waterworks (Bucks 5, S.W.), north-west of the town.

At Radclive springs are marked on the map (Bucks 13), about 690 yards north-north-west from the church and about 270 yards south-south-east from the same. Both are close to where the junction of the Cornbrash and the Great Oolite is shown on the geologic map (45, N.E.).

At Sherington three springs are marked (Bucks 5, S.W. and S.E.): 1, about 650 yards south-westward of the church. 2, about 270 yards north-north-west of the church. 3, at Crofts End, about 490 yards nearly south-south-east of the church.

At Stoke Goldington (Bucks 5, S.W.) a spring is marked by Bushy Yew, about 1,500 yards north of Gayhurst Church, and another nearly 1,220 yards a little east of north of the same. The water from the former is used for the Bath House (Gayhurst) over 300 yards south-south-east.

About a mile and an eighth south-eastward of Stowe House a spring is marked on the map (Bucks 13); but whether it rises from the Cornbrash or from Drift Gravel I cannot say.

A spring is marked at Tyringham (Bucks 5, S.W.), close to the Ouse, about 1,020 yards eastward of the church. Apparently this may be used for supply, as a "pumping machine" is marked close by.

Westbury, *see* Analyses, p. 282.

Such springs as are used for supply are mostly noticed under the heading Spring Supplies, p. 113.

MIDDLE OOLITES.

About 330 yards southwestward of New Arngrove Farm, in the parish of Boarstall, I saw, several years past, a pond which seemed to be fed by a spring, touching the Oxfordshire side of the county-boundary, and a little below, about 500 yards from the farm, were springs, just on the Buckinghamshire side of the boundary, which are said never to run dry. These places are at, or in the latter case just below, where the boundary-line of the Calcareous Grit (or Arngrove Stone) has been marked on the Oxford sheet of the Geological Survey Map.

I also saw springs in a like position about 330 yards north of Boarstall Church, and a line of others, one just above and two at the eastern edge of a little wood, both of which were ferruginous, about 1,000 yards south-eastward of the church, grey clay occurring directly below the lowest spring.

PORTLAND BEDS.

On the northern side of the Muswell Hill outlier two springs are shown on the map (Bucks 26, S.E.), in the parish of Brill, and the mapping of the streams at its western end, just in Oxfordshire, shows that there are several more.

T. I. Pocock has remarked that "Brill is surrounded by a number of fairly strong springs, but, owing to imperfect sanitary arrangements in the village, the waters have become more or less contaminated."[1]

The most notable set is in the well-marked valley southward from the village. I saw these several years ago with Mr. Parry, Surveyor to the Long Crendon District Council, and he gave me the following particulars :—

No. 1. Over 320 yards a little east of south from Manor House. Yield, 3,500 gallons a day. Water bad.

No. 2. About 190 yards south-eastward of No. 1. Yield, 7,200 gallons a day. Water bad.

No. 3. Some way southward of No. 2, and nearly 300 yards south of west from Parkdale Farm. Yield, 8,760 gallons a day. Water suspicious.

Analyses of these waters are given on p. 270.

Except along the north-western part of the overlying mass of Lower Greensand (where there is a very narrow outcrop of Weald Clay), there seems to be nothing to prevent the water of the sand from passing down into the Portland Beds. The village is wholly on the Lower Greensand.

At Long Crendon two springs are marked on the map (Bucks 32). One is about 250 yards west of south from the church, the other, "Lion Spring," about 860 yards southward of the church.

In the parish of Lower (or Nether) Winchendon a spring is marked on the map (Bucks 27) on the northern side of the outlier, between Muskhill and Marsh Farms.

On the Lodge Hill outlier a spring is marked on the map (Bucks 27), about 600 yards south-south-westward of Waddesdon Church.

H. B. Woodward says :—"At Whitchurch in Buckinghamshire copious springs are thrown out from the base of the Portland Beds. There is one beneath the moat of the Castle,"[2] the old earthwork, "Bolbec Castle."

There are probably many other springs along these outliers.

On the main outcrop "Dadbrook Spring (Chalybeate)" is recorded (Bucks 32), nearly half a mile south-south-eastward of Cuddington Church ; and G. MacD. Davies says that, at Hartwell, "the Egyptian Springs mark the junction of the Portland Sands with Hartwell Clay."[3]

LOWER GREENSAND.

Many of the outliers of this formation rest direct on Portland Beds, and then it is not likely that springs would occur, but rather that the water in the sand should pass down into the limestone, in the absence of any clayey bed between ; but at the most westerly outlier, Muswell

[1] 'The Geology of the Country around Oxford,' 1908, p. 128.

[2] 'Jurassic Rocks of Britain,' vol. v, 1895, p. 339.

[3] 'Geological Excursions round London.' 1914, p. 147.

Hill (Brill), a spring is marked on the map (Bucks 26, S.E.) just within the boundary of the sand and just below an unnamed farm (? Middle Farm).

Along the well-marked escarpment of the Brickhills there are many springs, and at Bow Brickhill some are used for public supply(*see* p. 113).

At Little Brickhill two springs are marked on the six-inch map, one over 300 yards west-south-west of St. Mary's Church, the other about 200 yards west of south from the church. Mr. Branson told me that their waters join, and that the combined yield, in June, 1888, was at the rate of 27,180 gallons a day. Gaugings in 1887 gave 62,240 (Mr. Taylor) and 84,657 (Mr. Nicholls), showing great variation.

In Back Wood, a spring (? by the parish-boundary at the eastern end of the wood) Mr. Branson recorded a flow at the rate of 46,350 gallons an hour, in June, 1888, and Mr. Nicholls gives the figure 87,096 in 1887. Another spring in the wood is credited with 16,405 and 30,918 by those observers. I believe that there are some other springs. Mr. Branson says that some of the springs here are said to have been dry in the summer of 1887.

Turning to Great Brickhill, at Brickhill Manor, across the road, northward of the house, a spring supplies a ram, and the yield was at the rate of 21,060 gallons a day, in June, 1888, according to Mr. Branson, and of 29, 800 in 1887, according to Mr. Taylor.

There are four springs, three of which are marked on the map (Bucks 20), about a quarter of a mile south and south-west of the church. Mr. Branson describes these as on Charley or Chartwell Moor (a name not on the map), and says that one boiled up to the surface, that all discharge into one outfall-ditch, and that the yield was at the rate of 84,000 gallons a day in June 1888.

Mr. Branson also records four springs near the old Coprolite works, the sites of which I cannot identify, with a flow at the rate of 28,159 gallons a day in June, 1888; and at Black Dog Spinney, south of Great Brickhill (not marked on the map), a spring with a yield at the rate of 135,264 gallons a day; but I feel in doubt as to whether a decimal point has not been omitted, the yield being so much larger than any other.

UPPER GREENSAND.

There may be small springs from the outcrop of this formation in Buckinghamshire; but I have no note of any. They are likely to be more in the nature of reinforcements to the streams from the Chalk-springs above than independent outflow.

CHALK.

General Note.

There are two distinct sets of springs from the Chalk. The smaller set, rising in Lower or Middle Chalk, at or near the base of the great escarpment, result in streams that flow in a general north-westerly direction, against the dip, passing therefore over formations below the Chalk, and draining into the Thame or some of the tributaries of the Ouse.

The larger set, rising in Middle or Upper Chalk, on the inner side of the escarpment, feed streams that flow in a general south-easterly

direction, with the dip, passing in their course over higher and higher beds of the Chalk, and ultimately, in many cases, across the overlying Tertiary beds. All these streams are tributaries of the Thames, and the springs are naturally subdivided according to the valleys in which they occur.

The origin of the two sets of springs is somewhat different. The escarpment-springs, as they may be called, generally start where a more permeable bed is underlain by a less permeable one, as at the base of the Chalk, where that formation is underlain by the Gault, and where a hard bed occurs in the Chalk, with less permeable Chalk below, as in the case of the Totternhoe Stone, at the top of the Chalk Marl or the Melbourn Rock at the base of the Middle Chalk.

The valley-springs, on the other hand, do not depend on the structure of the beds (except in the matter of the local occurrence of weak spots, from more open jointing, etc.); but simply on the saturation of the Chalk beneath them, so that water is stopped from sinking to a farther depth. In consequence of the fluctuation of the plane of saturation some of these springs are subject to great seasonal changes, even to the extent of drying up after long continued dry weather, and of remaining dry for long periods; such intermittent springs are treated apart, under the heading Bournes, or intermittent streams, a subject of much interest, especially in Chalk-tracts.

Escarpment Springs.

Writing of the Totternhoe Stone of Buckinghamshire, A. J. Jukes-Browne has said, "It is par excellence the water-bearing stratum of the district where it comes to the surface, its outcrop being marked by a line of frequent springs, most of which are utilised for the growth of water-cress."[1] It is the occurrence of these springs, and of those from rock-beds in the Chalk Marl that has led to the establishment of the many villages.

The spring north of Wainhill (Bledlow), by the county-boundary, seems to be from a lower bed, as also are the springs at the village. Of these Jukes-Browne says, in the Memoir above quoted, p. 61, "At Bledlow, on the eastern side of the church, there is a deep dell formed by springs which issue from the rocky beds in the Chalk Marl. This dell is about 25 ft. deep, and one band of firm marly Chalk occurs about a third of the way down, while at the base there is a very hard greyish sandy rock, out of the joints of which several springs of clear water issue. By the springs the rock is decomposed into a soft and sandy mass, but away from the water it is hard. . . . The level of this rock must be at least 40 ft. below the Totternhoe Stone." When first I saw this dell I was greatly taken with its appearance, and made the following remarks on it:—"Notwithstanding the water-cress beds, which far from improve it, this embryo combe is very pretty. The little hollows in its western side, their clear bright springs spouting out from the green-clad sides (sometimes with the moss and other plants encrusted with a calcareous coat from the trickling water), with here and there a patch of bare whitish marl, need but the sun lighting up the old

[1] 'The Geology of London,' etc., 1889, vol. i, p. 59.

church and glancing through the leaves of the tall overhanging elms to complete the picture."[1]

Continuing JUKES-BROWNE's remarks :—"The same rock-bed is to be seen at the spring-head south-west of Saunderton, and in the parish of Princes Risborough the spring east of Culverton (Pyrtle Spring of Bucks 37, S.E.) probably rises from the Totternhoe Stone, but it is generally dry in summer, while the strong springs near Princes Risborough rise from the lower rocky bed in the Chalk Marl. There is in fact a line of springs rising from this rock for some distance on either side of Princes Risborough, and as the spring-heads are all cleared out and utilised for the growth of watercress the rock can be examined in all of them. At Monks Risborough there are two springs, one S.W. and the other N.E. of the church, and the thickness of the rock appears to be from 4 to 5 feet."

"Other springs occur at Ascott,"[2] Askett of the newer map, in the parish of Monks Risborough.

He also notes the springs from the rock-bed in the marl at Great Kimble and those at Ellesborough, "which rise from the lower bed of rock in the Chalk Marl."

"The Well Head spring at Wendover rises from the Totternhoe Stone, pieces of which are thrown out of the water-course" (p. 63). But on the map the outcrop of that stone is marked some way below "Wellhead."

J. LUCAS has said the area of supply "was 4·6 square miles, and for the forty-five years, 1841 to 1884 . . . the annual mean flow might be taken . . . at 177 cubic feet a minute, which represented a mean percolation of almost exactly 9 inches per annum."[3] These figures seem to be got from a plate in which HERBERT THOMAS shows diagrammatically the yearly gaugings, which may vary from about 70 to about 320 cubic ft. a minute, based on a monthly record.[4] The springs seem to start at various points.

The Wellonhead Spring at Aston Clinton (Bucks. 34) is at the eastern edge of the Park, and seems to rise from the Marl Rock, a local hard bed in the Chalk Marl.

"In the escarpment of the Chiltern Hills the Lower Chalk is about 200 ft. thick, and north of Tring it shows several bands of gritty chalk, which give out springs and form more or less conspicuous features."[5] Cowhill Spring, marked on the map (Bucks. 30, S.W.) north-eastward of Pitstone church, is one of these.

A. M. BROWN has treated of some of the springs near Tring, especially of Dundale, "a pretty dell excavated in the Middle Chalk by a stream issuing from a spring."[6] He says, "The spring at Dundale is one of the four sources, in the Lower and Middle Chalk of Tring, of, originally, as many small streams, which, soon uniting north-westward from the escarpment, once flowed out of our county to the valley of the

[1] 'Memoirs of the Geological Survey,' vol. iv, 1872, p. 39. A specimen of the tufa was placed in the Museum at Jermyn Street. The plant chiefly found was *Marchantia polymorpha*.

[2] 'The Geology of London,' etc., 1889, vol. i, pp. 61, 62.

[3] In discussion, *Proc. Inst. C. E.*, 1891, vol. cv, p. 53.

[4] *Journ. R. Meteor. Soc.*, 1885, vol. xi, pl. v.

[5] 'Summary of Progress of the Geological Survey for 1911,' p. 31.

[6] *Trans. Herts. Nat. Hist. Soc.*, 1895, vol. viii, p. xxxiv.

Thame. The water-bearing beds producing them are the Totternhoe Stone, the Rag-bed of the Lower Chalk, some 40 ft. higher, and the Melbourn Rock."

"The Melbourn Rock, with its underlying marly bands, is probably responsible for 'Dundale' and the springs at 'Frogmore' in the town of Tring, and the Rag-bed for those at Miswell and Bulbourne Head, the latter sending two streams in opposite directions, one running south-east . . . the other north-west."

"By the construction of the Grand Junction Canal and its reservoirs at the end of the last (18th) century, and the erection of the Tring Silk Mill in 1824, all these streams were diverted, and a considerable length of those issuing from Bulbourne Head absorbed. The other three were conducted to the Silk Mill and thence . . . to the reservoirs."

"In 1889 Dundale was converted by Lord Rothschild into its present picturesque state by raising the level and increasing the extent of the water," etc.

At Hexton St. Faith's Well is marked by a wooden cross, and Bux Well (shown on map 220) near the head of the valley southward of the village, presumably is a spring from the Totternhoe Stone.

R. E. Middleton has recorded two springs at Pirton, one at Walnut Tree Farm, at a level of about 189 ft. above Ordnance Datum, presumably from Lower Chalk, and the other at Jeremiah's Tree, at a level of about 315 ft., presumably from Lower or Middle Chalk.[1]

In the neighbourhood of Hitchin there are some fine sets of springs at or near the outcrop of the Melbourn Rock, that is near the junction of the Middle and Lower Chalk, the water of which all flows to the little river Hiz.

One of them is at Oughtonhead, west-north-west of the town, where the resultant streamlets have given rise to a fair-sized patch of Alluvium.

Another set is at Well Head, south-south-west of the town, where, from the marked hollow westward of the farm, there is often a big flow of water, though I was told that it was dry in 1902. The stream is reinforced by other springs just below the farm, and probably by others, down to Charlton.

The third place, named Nine Springs, east of the town, just in the parish of Great Wymondley, is on another branch of the Hiz, some of the higher water of which probably comes from the gravel and sand of the Drift.

At Norton there are several strong springs, at Nortonbury Farm (north-eastward of the village), at a level not far below the 200 ft. contour, according to a letter from Col. L. S. Bowring, and there are others higher up the same valley, at Baldock, one (marked on the six-inch Map, Herts., sheet 7) at the parish-boundary, about a third of a mile westward of the railway-station. These are from the higher part of the Lower Chalk.

A. J. Jukes-Browne noted that at and near Ashwell the strongest springs are from the Totternhoe Stone.

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 643.

Thames Valley.

Prestwich has remarked that "a considerable spring burst out not much above the Thames level, at the foot of Taplow Hill, and no doubt on the floor of the Chalk, which was at yet lower levels in the valley (below), there were similar fissures through which the overflow water found a passage from the Chalk into the gravel."[1] One spring here is used for supply, (*see* p. 114).

Wye, or Loudwater and Misbourn Valleys.

At West Wycombe the spring at the head of the Wye is marked on the map (Bucks, 41), about 380 yards south-westward of St. Laurence's Church.

The highest parts of this and of other Chalk-streams are intermittent, and are described under the heading of Bournes. The chief records we have from the Wye and the Misbourn are from a paper by J. Lucas, which seems to find a place under that heading rather than here, as it deals largely with intermittence.

Bulbourne Valley.

The Dudswell Springs, high up the valley, are noticed elsewhere (*see* p. 100), as the borings there gave a good illustration of the effect of pumping at a neighbouring well.

Of the watercress-beds at Great Berkhampsted U. A. Smith says that they "suffered severely from the decline of spring-water. . . . With a view to improving the supply several boreholes were driven . . . during the year 1890, which at first yielded fairly well, but have since declined, and in the summer of 1891 some almost ceased to flow." Of the seven borings, from about 95 to 100 ft. deep, the height of the top of the tubes above Ordnance Datum varied from 350·94 down to 341·63 ft.[2]

The springs in these watercress-beds are again alluded to in the same volume, pp. 577, 578.

U. A. Smith says of St. John's Well, Great Berkhampsted, "This famous spring, which in former years formed a bath which was used for medicinal purposes, and then overflowed a good stream . . . was absolutely dry during part of the years 1890 and 1891, a circumstance not known to have previously happened. Since the heavy rains of last autumn this spring is again overflowing, but in very much reduced quantity. . . . The water level at the lip of the well on the 19th August 1892, was 343·02 ft. above Ordnance datum."[3] In the same volume (p. 549) R. E. Middleton says that the lowering of the water has been caused "partly by seasonal fluctuations and partly by local pumping at the Brewery and Waterworks." The subject is again referred to on p. 577.

U. A. Smith continues :—"Formerly there was a spring, having its origin and forming a pond in some meadows near Lock 55 on the Grand Junction Canal. This pond overflowed and formed a tributary to the Bulbourne, joining that river on the premises belonging to the Lower Mill. This tributary was also fed by other springs along its

[1] In discussion, *Proc. Inst. C. E.* 1891, vol. cv, p. 91.
[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 402.
[3] *Ibid.*

course, and at the outlet discharged a considerable quantity of water into the river. The head of this stream got gradually lower and lower down the valley, owing to the springs ceasing to flow, until in the summer of 1891 all traces of it disappeared, and, notwithstanding the heavy rains of last autumn, it has not reappeared."[1] The site has been built over.

The springs in the moat of the old castle also failed in the early part of 1891, "an occurrence not known previously."[2] They recovered later, to some extent, at all events. (Middleton.)

Continuing U. A. Smith's description of 1893, at the watercress-beds north-west of Bourne End, "there has been a gradual decline of the springs for some years. . . . In consequence . . . several boreholes were sunk in these beds in the year 1890, in order to increase the supply of water. The eight borings were about 90 ft. deep, and the height of the top of the tubes above Ordnance Datum varied from 310·52 down to 304·44 ft."

The watercress-beds at Bourne End are partly fed from the Canal, so that the decline of the springs has been less felt. "Three bore-pipes were driven down in these beds in the early part of the year 1900. . . . One . . . at first overflowed . . . but the quantity gradually decreased until in March, 1891, when the springs formerly used to be at their highest level, no water at all was coming from this pipe, and the quantity from the two other tubes had very materially decreased. Within a few months of the completion of the first three borings six more tubes were sunk . . . with a like result. All the borings were from 80 to 100 ft. deep and the height of the top of the tubes varied from 302·75 to 300·43 ft. above Ordnance Datum."

These borings are again referred to on pp. 579, 580 of the same volume.

There are also springs in the watercress-beds by Apsley Mills and Nash Mills, which are said to have decreased in volume.[3]

Gade Valley.

U. A. Smith has noted springs at Water End, Great Gaddesden, which feed watercress-beds; but in the early part of 1891 they were dry. There are also other springs feeding watercress-beds along the valley.[4]

R. E. Middleton notes that a spring at Noak Mill, a little lower down, "went dry in 1891, and it has not recovered"; but he doubts if it is a chalk-spring, and later on he says it is probable that the supply has been cut off at the watercress-beds . . . to the south east . . . made some four years ago." I have a note of springs at the head of the watercress-bed, touching the high road north of the Mill.

Springs in the watercress-beds at Berry (? Bury) Park (not marked on the map) are said to have decreased in volume.[5]

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[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 402.
[2] *Ibid.*
[3] *Ibid.*, p. 580.
[4] *Ibid.*, pp. 390, 400, 550, 551.
[5] *Ibid.*

Ver Valley.

U. A. Smith has given us notes of many springs in this valley,[1] which will now be noticed.

The highest spring recorded is at Kensworth. "This spring formerly rose to the North-west of Kensworth Lynch, and was one of the principal sources contributing to the . . . River Ver. The spring has not overflowed to form a stream since the year 1883, and the water-course below it for perhaps two miles is now dry." There can be no doubt, however, that, as R. E. Middleton says, in the same volume (p. 553), "there never was any permanent spring at Kensworth Lynch." He also notes some springs at Flamstead (p. 582).

The next springs we hear of (from U. A. Smith) are at Redbourn, one of which, in February, 1891, was the highest source of the Ver. Others feed watercress-beds.

At Redbournbury Mill there is a spring in the basement of the house.

There are springs in the watercress-beds down to and at St. Albans, and in the neighbourhood of Holywell Hill, "the level of the water standing in the beds is much affected by the pumping at the City Waterworks well at the bottom of Holiwell Hill . . . although the beds and the pumping station are nearly half-a-mile apart."

"The level of the water in a spring on the premises belonging to Sopwell Mill has gone down fully 12 in. in the course of the last few years."

At Park Street the watercress-beds "are principally supplied by a number of small springs, the flow of water from which has been gradually decreasing for a number of years, and the total decline has been as much as 25 per cent."

Colne Valley.

We come now to a set of springs with a literature; but unfortunately the *Otters Pool* has been marked wrongly on the old map, sheet 7, as in Bushey or Watford. As shown on the newer map, 256, the place is some two miles higher up the valley, in Aldenham, by the Colne west-north-west of the church.

The springs at Otterspool were thus described in 1876:—"Here there is a remarkable pool, at the bottom of which are several springs which now yield about 300,000 gallons of water a day, and are said at times some years ago to have yielded a million. These springs are part of a series which rise along the valley by lowering the reservoir of water in the chalk, and here seem mostly due to the rain which falls on the adjoining Eocene area, and percolates through the Lower Eocene sands and Drift gravels into the Chalk. The pool was by sounding found to be 16 ft. deep at the deepest part; and the water is so clear that the springs themselves, and the sides of the fissure in the chalk which forms the pool, can be distinctly seen, and so cold that wine is iced [cooled] in it."[2]

In the same year Clutterbuck referred to these springs and suggested that they were connected with swallow-holes (*see* p. 84), a view accepted by Hopkinson in 1885.[3]

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[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, pp. 403-4.
[2] Anon. *Trans. Watford Nat. Hist. Soc.*, vol. i, p. xv.
[3] *Trans. Herts. Nat. Hist. Soc.*, vol. iii, pt. 4, p. xlvi.

In 1893 we had the following notes, from U. A. Smith[1]:—"The mouth of the spring . . . is some 40 ft. in diameter and 20 ft. deep. The spring yields a much smaller quantity than formerly," depending, of course, to some extent on the rainfall.

"There are several springs in the bed of the river where it passes through the grounds of 'Otterspool House' the quantity of water in the river being increased by the flow from these springs as much as 25 per cent. during its flow through these grounds, a distance of about 150 yards."

In the same volume (p. 567) S. T. Holland said that since 1873 until 1890 the water has never ceased to run over, but in 1890 on several occasions the sill (over which the water flowed) was perfectly dry, and the same occurred again in 1891, but it has not happened in 1892." The falling off began in 1887.

R. E. Middleton adds (p. 557): "A permanent reduction of 1 ft. or thereabouts in the level of the water in the chalk basin would have caused this spring to cease to flow." He also refers to the spring on p. 599.

Lea Valley.

The highest set of springs in the Hertfordshire part of the Lea of which I can find a record[2] are those in the watercress-bed at Batford Mill, Wheathampstead (1¾ miles above the village). Others occur at Castle Farm, where "there is in particular a large, circular bed about 30 yards across. The *springs* used to rise strongly all over this bed, and the water was knee deep. Now the springs are very feeble and the water not over the ankle." Probably since that time they would have again been knee-deep, had not the drains been cut so as to lower the water (p. 559).

At Lemsford watercress-beds, in the northern part of Hatfield parish, two miles from the town, the same author says: "There has been a gradual decrease in the flow of the springs" which "now do not yield more than two-thirds of the quantity they did fourteen years ago."

The spring marked on the map (Herts. 28, S.E.) on the right (western) side of the river, about 550 yards north-eastward of St. John's Church (by the southern end of Brocket Park, in 28, S.W.), in the parish of Hatfield, may rise from Chalk or from Drift gravel.

We now come to a noted set of springs known as *Arkley Hole*, in Woolmers Park.

In 1893 R. E. Middleton recorded that the agent for the Woolmers Park Estate, who had known the springs more than 36 years, said that "the spring was lower in 1890 and 1891 than he has known it; at present there is a good flow. There was a very dry season in 1870-71, but at that time the spring did not fail until later in the year." He adds: "There is another spring on the other side of the river, which neither fails nor varies. An examination of the well sections (water-levels in the tract between) appears to point to these springs being supplied from North Mimms." The swallow-holes at that place have also been credited with the Chadwell spring, (*see* p. 57). The

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 397.
[2] U. A. Smith. *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 406.

spring on the other side of the river is probably the one marked on the six-inch Ordnance Map (Herts. 36) a little east of south from the house, and it is 2 ft. above the stream.

In 1898 I alluded to this spring, which is in Spring Wood, at the eastern edge of Woolmers Park, in the parish of Hertingfordbury, close to and on the northern side of the Lea, the surface of which is some 6 ft. below the spring. It is in a like position to the Chadwell Spring, and also has its water clouded after rain ; here, too, the Chalk is largely covered with Glacial Drift, chiefly of a clayey kind ; so that there is no difficulty as to a local origin of the cloudiness.

In 1898 J. Hopkinson wrote[1] that he had heard that about ten or eleven years before, "the rushing of the water over the outlet of the pool which this spring has formed, could be heard at the house a quarter of a mile away. Now silence reigns supreme, for the spring is dead. It was noticed that it was ailing about eight years ago, and its decline was rapid. . . . There is a spring on a lower level, very near it, which has never been known to fail, but which now yields only a small quantity of water."

Joseph Francis, then Engineer to the New River Co., wrote to me on 20th September, 1898, that on visiting the spring he had found no discharge, the water in the pool being stagnant, standing about $2\frac{1}{2}$ ft. below the overflow and $4\frac{1}{2}$ above the Lea. There was, however, a strong spring about 30 yards off, delivering water along a short branch-cut, from about 2 ft. above the Lea. This he had never known to cease flowing ; the discharge was at the rate of 70,000 gallons a day at 51° F.

I saw these springs last in February, 1904, and then the water at Arkley Hole was cloudy. There is another spring just south-east of the Hole.

J. M. Wood tells me that on June 30th, 1920, Arkley Hole Spring was active, but discharging no great quantity : it was hard to say how much, the outlet being much overgrown.

The spring marked on the map (Herts. 29), about half a mile north-eastward of the house at Bayfordbury, is in a narrow tract of gravel ; but possibly the water comes up from the Chalk.

It is convenient here to notice some general remarks on the springs of that part of the Lea between Hatfield and Hoddesdon.

In 1851 Sir J. Prestwich wrote, "The large springs of Chadwell, near Ware, and others between Hertford and Hatfield appear to me to be probably owing to the operation of an east and west *fault*, dislocating the strata, and stopping part of the water in its subterranean course from the hills north of Ware and Hertford. In the Chalk a very small fault would suffice for this object."[2] But this view would hardly be held now, and there is no occasion to call in the aid of a fault (of which there is no geologic evidence) : the water finds its way out where there is a fairly free channel, however that is caused.

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[1] *Trans. Herts. Nat. Hist. Soc.*, 1899, vol. x, p. 73.

[2] 'The Water-bearing Strata around London,' p. 74, footnote.

In 1867 R. W. Mylne drew attention to the copious springs in the valley of the Lea.[1] He speaks of the "numerous springs issuing from an extensive chalk district, the greater part of which is covered with large tracts of sand and gravel which act as a permeating medium of storage, equalizing the flow and giving their maximum discharge in the summer seasons."

Springs between Amwell and Rye House vary in volume (said to yield to the extent of 8,000,000 gallons a day), "and are affected in colour in wet weather, but their discharge is highest in summer."

Springs "between Hoddesdon and Broxbourne below Feilde's weir are of a much more permanent character, probably arising from a considerable extent of drift area to the westward," and these yield in dry seasons about 6,000,000 gallons a day.

He thought that the water from the Mimms swallow-holes (*see* p. 86) largely found its way out in springs between Hertford and Hoddesdon. "The source of the Chadwell spring, though deep-seated, may possibly be influenced from the same circumstances, and its volume, though variable, may be taken at about 4,500,000 gallons per diem."

We now come to the consideration of one of the most notable springs in the kingdom, the *Chadwell Spring*, which was originally the head-water of the New River, that wonderful scheme of water-supply for London which was completed more than 300 years ago, in 1613, and the first object of which was to take water from the springs of Chadwell and of Amwell to London. Though the New River now starts direct from the Lea, a little higher up, the spring has continued to be one of the sources of supply and probably will continue, though the Amwell Spring has long ceased to be of material service.

The number of Royal Commissions and Parliamentary Committees before which the Chadwell Spring may be said to have appeared is considerable: probably no other spring has figured so largely in this way, and the literature that has ensued is bulky, and of course with much repetition. It is hoped that in the following account all the main matters have been noticed.

The spring is in the parish of Little Amwell, by the southern edge of the Marsh, but little eastward of the boundary with Hertford.

The following table shows the importance of the spring as a yield of water and the great fluctuation to which that yield has been subject:

[1] *R. Comm. Metrop. Water Supply, Minutes of Evidence*, 1869, pp. 281, 282.

AVERAGE DAILY DISCHARGE OF CHADWELL SPRING, in 1,000 gallons. Weekly Measurements. Condensed from *R. Comm. Metrop. Water Supply*, 1893, *Appendices*, pp. 6, 7. With additions (from April, 1892) from the New River Co. (for Bill of 1896), and with further information from J. M. WOOD, of the Metropolitan Water Board.

——	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
January	3,438 to 3,852	3,249 to 3,735	540 to 2,520	3,780 to 4,059	3,402 to 2,772	3,186 to 2,727	4,446 to 3,933	3,330 to 2,745
February	3,591 ,, 4,554	3,870 ,, 4,365	1,989 ,, 2,997	3,609 ,, 4,590	4,023 ,, 3,465	3,798 ,, 3,402	4,275 ,, 2,925	2,979 ,, 2,250
March	3,915 ,, 4,698(*a*)	3,051 ,, 3,879	2,079 ,, 3,606	3,393 ,, 4,644	4,320 ,, 4,032	4,110 ,, 3,249	3,582 ,, 3,222	4,203 ,, 2,241
April	3,744 ,, 4,194	3,429 ,, 4,086	1,980 ,, 2,907	4,203 ,, 2,817	4,626 ,, 3,465	3,447 ,, 2,367	4,374 ,, 3,078	4,383 ,, 2,988
May	3,744 ,, 4,104	2,259 ,, 3,762	1,458 ,, 3,195	3,474 ,, 2,349	2,925 ,, 2,754	2,133 ,, 1,827	2,628 ,, 1,998	2,232 ,, 1,485
June	3,654 ,, 4,680	1,872 ,, 2,313	1,224 ,, 2,493	2 583 ,, 1,764	2,619 ,, 1,962	1,926 ,, 1,143	1,800 ,, 837	1,602 ,, 1,089
July	3,555 ,, 3,771	2,097 ,, 3,033	675 ,, 1,404	1 773 ,, 1,062	1,800 ,, 1,152	1,179 ,, 531	1,197 ,, 675	1,026 ,, 585
August	3,006 ,, 3,672	1,665 ,, 2,250	729 ,, 1,161	1,395 ,, 567	1,116 ,, 612	666 ,, 522	1,719 ,, 1,026	585 ,, 504
September ..	2,772 ,, 3,078	909 ,, 1,746	450(*b*),, 900	1,737 ,, 900	684 ,, 504	639 ,, 504	909 ,, 504	2,196 ,, 792
October	2,592 ,, 3,501	783 ,, 1,134	450(*b*),, 3,231	2,205 ,, 1,170	684 ,, 513	504 (all)	891 ,, 585	3,897 ,, 3,168
November	3,105 ,, 3,510	936 ,, 1,602	3,006 ,, 3,798	3,906 ,, 2,871	1,818 ,, 504	3,654 to 1,872	2,943 ,, 504	3,789 ,, 3,240
December	3,024 ,, 3,555	720 ,, 1,773	3,609 ,, 4,320	3,807 ,, 3,096	2,790 ,, 1,728	3,924 ,, 3,105	3,303 ,, 2,916	4,383 ,, 3,636
Average for year ..	3,618	2,412	2,001	2,736	2,205	2,160	2,242	2,475

The low averages for 1890 and 1891 are owing to the scantiness of the rainfall during the ten months preceding the summers of those years.

(*a*) highest; (*b*) lowest. In these two cases the figures are estimated, as trustworthy gaugings could not be made when the discharge is less than 500,000 gallons.

This is supplemented, for earlier and later years, by a return prepared, I believe, in relation to Barnet Water, the figures standing for the average flow per day in the years noted, in millions of gallons.

1881	3·47	1897	2·83
1882	3·36	1898	·75
1883	3·64	1899	1·14
1884	2·1	1900	1·36
1885	2·73	1901	·74
1886	3·25	1902	·24
1887	2·5	1903	1·95
1888	2·7		

In 1898 I ventured to make various remarks on this spring[1] based on visits made some time before, some of which will now be noticed.

One peculiarity is that the water becomes cloudy soon after a considerable amount of rain. On my last visit one could not see anything 18 in. below the surface of the water, whereas generally in Chalk-springs one can see deep down, indeed to the bottom in any but very deep springs.

It had been suggested that this cloudiness is owing to the muddy water, from the slopes of Tertiary clay, that finds its way into the Mimms swallow-holes, which water had been thought to flow in this direction. This theory, however, has its difficulties, for it involves either an absence of filtering power in a very great length of Chalk, or the presence of a direct and fairly open channel through the Chalk for some nine or ten miles, and a speed of flow, down a by no means rapid incline, which does not allow of the subsidence of the suspended particles. A note from J. M. Wood (*see* p. 88) seems to dispose of this theory. He adds that the cloudiness, which follows within a few hours after heavy rain, may be due to clayey water down swallow-holes a very short distance north-westward of the spring.

On the other hand, a simple explanation can be given, and this should be taken rather than the above ingenious one. The Chalk-hill directly above the spring has a capping of Glacial gravel (in which there are often clayey or loamy beds), and this may account for the cloudiness of the water after heavy rain.

Whilst therefore not disputing the northerly flow of the water from the Mimms swallow-holes, I doubt that it goes so far eastward as Chadwell.

In the autumn of 1898 this spring failed, and this failure gave rise to various letters, etc., in local newspapers. These, however, may be passed over, the subject being fully dealt with in the publication next to be noticed.

In 1899 we had from J. Hopkinson a paper on the Chadwell Spring, from which the following remarks are taken,[2] some being of a general character.

"For nearly three centuries has water been conveyed to London from the Chadwell Spring, and up to the autumn of the present year (1898) there is no recorded instance of the failure of this spring. About the beginning of last September it was noticed that instead of water flowing out of the basin of the spring, there was a considerable flow into it, the current in the cut which connects the spring with the New

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. x, pt. 1, pp. 2–5.
[2] *Ibid.*, pt. 3, pp. 69–75, 81–83.

River being reversed. A dam was then erected across the cut, and the water of the River Lea thus being prevented from flowing into the basin of the spring, the level of the water in it sank several feet—nine feet, it was reported, but it was scarcely seven feet below the outlet when I visited it, with . . . . Mr. Whitaker, on the 24th of September."

"It is evident that when . . . the current of the water was reversed, the spring, or group of springs, was acting as a 'swallow-hole.'"

"Water will not flow out of a spring unless there is water at a higher level than the outlet of that spring; it is the weight of the water above which causes the spring to rise; and that water above, when held in the pores of unfissured Chalk, can only gradually take the place of the water which flows out. Hence springs in the Chalk are . . . 'permanent'; they do not depend upon the rain which falls at the time—they do not ebb and flow with the rainfall. It takes a long time for the rain to saturate the Chalk, and a long time for the water to drain out of it into the springs and rivers."

"It therefore appears that the Chadwell Spring could not be flowing freely one day and absorbing water copiously the next; that when . . . water was flowing into the basin, it must have ceased to flow out of it for some time; and that the extent to which the water fell when the River Lea was stopped from flowing into it is a measure of the length of time which had elapsed since the spring ceased to flow. The reason why the water fell so many feet immediately the supply from the Lea was stopped, is that the plane of saturation in the chalk had fallen to that extent, probably having been sinking for some months."

"I believe that it is a rule about six or seven weeks before the spring fully responds to the rainfall . . . that it is nearly as long before dry weather affects it; and that if our reservoir of saturated Chalk were in its natural state a fall of several feet in its level would be the result of a dry period many months beforehand. But it is not in its natural state; the large amount of water pumped up from great depths unnaturally exhausts it and . . . the plane of saturation sinks more rapidly . . . when the rain is in defect and rises more slowly when it is in excess."

He treats of rainfall, percolation, and the changes in the flow, as recorded by various observers. In 1852 W. C. Mylne recorded a minimum of 2,600,000 gallons a day, "a minimum considerably in excess of the present *average* yield." In 1857 (? 1867) J. Muir stated that the above minimum was a rare occurrence, that the average was 3,600,000, and that in the beginning of the year (1866?)[1] the yield was 6,300,000. In 1867 the same observer gave the average yield in 1866 as 4,500,000 gallons a day.

In 1874 the Rivers Pollution Commission concluded that the minimum yield up to that time had been 2,592,000 gallons a day and the maximum 6,336,000.

"The very great diminution in the flow of this spring in the five years 1891-96 coincides with the permanent failure of the spring at Woolmers (*see* p. 53), and took place during a period of more than average rainfall."

[1] These dates are inserted on the authority of the 2nd Report of the Rivers Pollution Comm., vol. ii, p. 40, in which the minimum yield in 1864, is given as 2,610,000 gallons a day.

"In a quarter of a century the New River Company has increased the amount of water taken from the valley of the Lea by 14 million gallons a day . . . from wells and springs, and, as the springs are yielding less, the draught upon our underground reservoir of saturated chalk by means of wells must have increased to a greater extent than this."

On August 31st, 1898, Sir J. Evans "wrote a letter to 'The Times,' in which he said that 'if the pumping is excessive, the natural courses through which the springs would rise into the stream will be conveyed by gravitation into the wells.' When this was written, the very thing which he predicted was, unknown to him, actually occurring at the Chadwell Spring."

The plate accompanying this paper is from a photograph of the basin of the Chadwell Spring whilst being cleaned out, the water being kept low by pumping.

I had the pleasure of seeing the spring with Mr. Hopkinson, and I noticed that the bottom part was thickly coated with mud, and I think that this deposit has not, at all events, improved the flow from the set of springs. The water was taken out, by a powerful pump, so as to clean out the basin.[1]

In 1901 R. E. Middleton said that the Chadwell Spring failed in 1898, "and since, to the extent that it did not overflow; but in any other sense it did not fail, for the New River Company were able to pump some 500,000 gallons of water (a day) from it."

"The Chadwell Spring was within the cone of exhaustion of at least two of the New River Company's wells, and might therefore have been depleted by them."[2]

In the following year U. A. Smith[3] said:—"Until the last few years this spring has given an uninterrupted supply of water for nearly 300 years. During the last 10 years the pumping by the New River Company has been gradually increasing, and . . . the flow of the Chadwell Spring has been gradually decreasing, until, on the 26th of August, 1898, the flow . . . ceased for the first time in its history. The Spring did not resume its flow until November 30th." And it "has ceased to flow each Autumn since that of 1898, and upon each occasion has been inoperative for a longer period, as set out below." For pumping interference here *see* p. 103.

Cessation of Flow.

1898.	26th August to 30th November	= 68 days.
1899.	24th June to 6th November	= 132 days.
1900.	17th July to 24th November	= 139 days.
1901.	18th June to 28th December	= 193 days.

I cannot, however, understand how the number of days is arrived at: the first three figures should be 96, 135 and 130, the fourth only seems right.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1899, vol. x, pt. 4, pp. 105, 106.

[2] *Trans. Surv. Inst.* vol. xxxiii, pt. v, p. 188.

[3] 'Underground Water Preservation Association'. . . 1902? (undated), p. 30.

According to T. C. Myddelton "the average discharge of the Chadwell Spring in cubic feet per minute for certain weeks" was as follows:

1902, 1903.	week ending	3rd January,	*nil.*
1903,	,,	,,	4th April, 243.
,,	,,	,,	13th June, 17.
,,	,,	,,	7th November, 424.
,,	,,	,,	20th December, 405.
1904,	,,	,,	9th April, 382.

"the decrease having been daily and gradually since the 7th of November, 1903. Thus it appeared that the Bourne (*see* p. 71) broke out about the time of the maximum discharge of the Chadwell Spring, but that while that spring gradually decreased in volume from November to April, the Bourne increased . . . from its rise in the middle of November to the end of February."[1]

The latest paper on Chadwell Spring is by J. M. Wood,[2] and it gives us the most exact description. This set of springs was the original source of the New River, and is in "an approximately circular basin . . . having a diameter of about 90 ft. The springs rise nearly in the centre of the basin in several well-defined fissures. The maximum depth of the basin is about 16 ft. A few yards beyond the outlet of the basin into the river there is a wall or dam built across the river in which a weir is fixed for measuring the discharge from the spring. This wall was built in 1898, when the river was found to be running back into the spring to a considerable extent. There was nothing new in this 'running back,' although one was not actually aware of it, as there existed no absolute means of measuring the discharge until the weir . . . was fixed, but on searching the old records it was found that the spring had actually failed (at periods of low rainfall) on several occasions in the last century and particularly in the year 1855, which was before any pumping from wells in the valley worth speaking about had taken place. The discharge from the spring varies considerably, which can be seen from the numerous returns made to the several Royal Commissions, and appears to be affected directly by the rainfall, and the pumping in the valley. The saturated line (plane) or water gradient in the chalk undoubtedly varies considerably in the neighbourhood of the spring, becoming steeper or flatter, as the case may be, due to an excess or deficiency in the rainfall, and may be called the wet and dry saturation line (plane). These grades are also affected by pumping, and when these disturbing elements, low rainfall and heavy pumping, act together, the grade flattens down to such an extent as to fall below the discharging level of the spring."

"The cones of depression set up by pumping from the several wells in the neighbourhood of the spring, particularly those in Amwell, about 1½ miles lower down the valley, undoubtedly intersect the natural line (plane) of saturation leading to the spring, as the pumping from these wells affects both the level and yield of the spring. The fissures feeding the wells are undoubtedly in direct communication with those feeding the spring, although more than 1½ miles distant. This is what one would naturally expect, as the greater the pumping from the Chalk the more the fissures become open and discharge more freely."

[1] J. Hopkinson, *Trans. Herts. Nat. Hist. Soc.*, 1906, vol. xii, pt. 8, p. xlii.
[2] *Proc. Geol. Assoc.*, 1909, vol. xxi, pp. 247, 248.

We can finish our account of this Spring by a quotation from a letter by Mr. Wood, dated 18th April, 1916: "The Chadwell Spring and the Amwell Springs are yielding more than I have ever known them to do." It was, of course, a notable season for bournes and springs.

"There is a spring with a good flow near the junction of the Rivers Ash and Lea, and about 100 yards from the Lea."[1]

The *Amwell Spring* is less than 50 yards from St. John-the-Baptist Church at Great Amwell.

The following two paragraphs are by U. A. Smith and R. E. Middleton:—[2]

The watercress-beds at Amwell "are fed principally by a spring flowing from the side of a hill, and which is most seriously affected by the pumping operations of the New River Company. When the pumps at the Amwell Marsh and Amwell Hill stations are being worked at the same time, the beds are drained dry in two hours, and the pumps at either station diminish the flow of the springs by from 33 to 50 per cent."

R. E. Middleton adds:—"A special experiment was instituted on March 23rd, 1893, to test this statement, and it was found that after six hours' continuous pumping the strength of this spring had been reduced about one-third, while some ditches, ponds and springs in the neighbourhood had become dry."

In 1899 J. Hopkinson remarked that "Fair Emma's Well has long since ceased to flow."[3] But in 1901 R. E. Middleton supplemented this as follows: "The Emma Well or Amwell Spring, which was . . . one of the sources of the New River . . . runs now, except when pumping to a considerable extent is carried on at the Amwell Hill and Amwell Marsh pumping stations, when this spring, along with other smaller ones close by, partially or wholly fails."[4]

In 1909 J. M. Wood said of this spring that "it is practically under the same conditions as Chadwell Spring, and is affected by the same causes and appears to be connected with the same system of fissures, but with this difference, that it is more sensitive to local pumping in the valley." It "now rises below the bed of the river (Amwell Pond), and I assume that this spring was so diverted in early times so that the river might not discharge into the spring at periods of low rainfall."[5]

Of the watercress-beds between the railway and the river a little north-westward of Rye House it is said, by U. A. Smith:—"A continuous decline in the springs has been noticed here for 18 to 20 years, that is, from the date that pumping was commenced at the Essex Road (Hoddesdon) Station of the New River Company. The springs grow weaker year by year, and now, within half-an-hour of the . . . pumps being started, 50 per cent. of the present diminished supply is lost."

R. E. Middleton allows "that all springs, ponds and streams within the influence of the pumping stations are lowered thereby, while the pumping continues, is certain, but the effect is strictly local."

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 612.
[2] *Ibid.*, pp. 406, 559, 560.
[3] *Trans. Herts. Nat. Hist. Soc.*, vol. x, p. 73.
[4] *Trans. Surv. Inst.*, vol. xxxiii, pt. v, p. 188.
[5] *Proc. Geol. Assoc.*, vol. xxi, p. 248.

The subject of the effect of pumping on these springs is again discussed, and details of the experiment of March, 1893, are given on pp. 613, 614 of the same volume.

J. M. Wood writes (1920) that, as far as he knows, the springs are not affected by the pumping at the Hoddesdon Works of the Metropolitan Water Board; but that they may be by that at the Rye Common Works, a quarter of a mile northward of the springs. The pumping at the well of the Hoddesdon Water Works Company may also have some small effect on the springs. But the effect of the pumping at the three works does not destroy or permanently affect the springs.

The pond at The Lynch, on the eastern side of the New River, over a third of a mile south-east from St. Catherine's Church, Hoddesdon, is filled by springs. It is probably to this place that A. C. Harston referred, in a letter of 1894, saying that there is a *hot* spring in a lake near the flour-mill (abandoned), and that the water from this lake is drawn off by a pipe across the road and used in the watercress-beds, for which the warm water is valuable.

There seems to be another spring in the stream at the northern end of the watercress-beds, southward of the pond.

Of the watercress-beds near Broxbourne U. A. Smith says :—"The decline in the springs . . . has been noticed ever since the New River Company commenced pumping at their Essex Road station some 18 years back. The springs continue to gradually decrease, the supply being at least one-third less than formerly. When the pumps at the Broxbourne and Essex Road pumping stations are worked simultaneously a very extensive bed is drained quite dry."

"There is in the Broxbourne Gardens a fine chalybeate spring. This spring formerly rose up through an ornamental fountain and filled a small pond and overflowed to the River Lea . . ."

"Some four or five years ago the New River Company commenced to pump at its new large pumping station, Broxbourne. The springs in Broxbourne Gardens . . . about half-a-mile from the pumping station, across the . . . River Lea, almost at once ceased to flow. The spring has never recovered its former volume," though when pumping was stopped it began to trickle.[1] J. M. Wood writes (1920) that the Broxbourne Pumping Station probably affects springs in the Valley more than any other Station does.

The Broxbourne springs are also referred to by R. E. Middleton in the same volume, pp. 615, 616. The spring in the Gardens is about 880 yards from the pumping station.

Mimram Valley.

The following notes on springs above Whitwell (St. Paul's Walden) are by U. A. Smith.[2] A "spring rises in a deep hole in a meadow known as the Meads, situate about one mile from Whitwell. During the spring and summer of 1891 the spring was practically dry, an event which certainly had not occurred during the past 30 years." The head-water of this stream is naturally intermittent.

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[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 406.
[2] *Ibid.*, p. 408.

Of the watercress-beds near Whitwell he says :—A gradual decrease in the supply from the springs has been observed for the past nine years, and it is estimated that during that period the decline has been fully 50 per cent. A borehole has (since 1891) been sunk with a view to increasing the supply.

There is also a spring in the side-valley between Kimpton village and mill.

Lower down the valley a spring is marked on the map (Herts. 28, N.E.), near the river by the western end of Oakhills Wood, about 1,030 yards north-westward of Welwyn Church. Just north of Tewin Mill (Herts. 29) is another, but whether these come from Chalk or from gravel I cannot say. The spring marked on the map (Herts. 28, S.E.), westward of Mount Pleasant, Tewin, is from Chalk.

Dr. R. L. Sherlock tells me that there is a spring at Dell Cottage (St. Andrew's, Hertford), just north of Hertingfordbury.

Beane Valley.

At Luffnell (Luffenhall), above Walkern, there is a spring in a pond which "has never been known to fail entirely, but in 1891 it was weaker than it had been for many years."

"The main springs forming the chief source of the river apart from surface water are those between Walkern and Cromer." [1]

R. E. Middleton says :—"Just above Walkern Church there are several clearly defined springs, which . . . in February, 1893, were flowing freely."

"In 1891, and on former occasions, these springs ceased to overflow."

"It appears as if there were a small fault here or a bed of clay (*see* Wells, p. 256) . . . and that these springs are held up above the normal level of the water in the chalk basin."

"It is possible that these springs draw their supply from the swallow holes at Walkernbury." [2]

Other springs noted are above Frogmore (still on the main stream), above Watton, at Watton Mill (in the cellar ?), and at Watton House. These may come from Drift which there hides the Chalk, as is also the case at Oak's Cross Farm, a little way up the Stevenage branch, which R. E. Middleton thinks to be a Chalk-spring (p. 563).

It is said that there are five springs about Holbrook Farm, Benington, though some of them may be in the parish of Aston, four below and one above, but blocked with earth and vegetation. One was cleaned out, "but it was in quicksand and ran in again and they could not keep it open." [3]

On the same page it is said : "There is a spring east of Hebing End (Benington), which is always running quite clear water." This is in a side-valley of the branch of the Beane dignified with the name of Old Bourne.

[1] U. A. Smith, *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 409 (*see also* p. 391).
[2] *Ibid.*, pp. 562, 563.
[3] *Ibid.* 1893, p. 632.

Later on (pp. 624-627) Middleton alludes to springs higher up the valley than any above noted, at Weston and Rushden (Shaw Green). These may come partly from Drift, as he suggests ; but the subject needs examination. That at Shaw Green is said never to dry.

Rib Valley.

R. E. Middleton says "At Westmill there are a number of springs which are probably supplied from the chalk . . . but this is not certain"[1]; and there are said to be several small springs at the junction with the Quin (p. 638).

U. A. Smith says that at Quinbury, Braughing, in the tributary Quin Valley, a spring "used formerly to rise in the cellar at the farm, 10 ft. deep, to such an extent that it was necessary to empty the cellar three or four times a week. During the last ten years the water has only twice appeared in the cellar, and neither time to anything like such an extent as formerly."[2] Of this one can only say that it seems to be a case of seasonal fluctuation in a rather weak spring, as a strong one could not be emptied out.

According to R. P. Greg and R. B. Croft the highest spring on the Quin seems to be at Rushing Well, near Nuthampstead, and at Biggin Moor, a little lower down, there are several springs. "In a field above Braughing Vicarage there is a considerable spring, and the river is further augmented by the overflow of a spring which forms a pond in the Vicarage garden, which has never been known to freeze."[3]

Ash Valley.

Springs have been noted about Much Hadham (some in Knights Meadows), and these used to run continuously, but had not (1893 ?) flowed for five or six years. Some of them may come from Drift.

Dr. R. L. Sherlock notes that two springs are marked on the map (Herts. 30, N.W.) at Baker's End, in the parish of Thundridge, at the head of a small tributary.

DRIFT, GRAVEL AND SAND.

A great number of small springs are thrown out from these highly permeable beds wherever clayey beds crop out from beneath them, of which only comparatively few can be noticed. It is immaterial to consider here the particular age of any gravel, whether Glacial or Post Glacial : all are alike in the matter of water.

In some cases my information is taken from such six-inch Ordnance Maps as I have ; but in examining these I found that the word "spring" is in many cases used merely for a wood.

In *The Mirror*, No. 543, April 21, 1832, p. 248, is a short note of Queen Anne's Spring, at Chalvey, near Eton. Queen Anne is said to have used this water and Queen Charlotte for many years had some of it taken to Windsor.

In 1888 W. Topley noted a spring at Wellmore, at the eastern end of the village of Maids Moreton, the level of which is 344 ft. above

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 564.
[2] *Ibid.*, p. 409.
[3] *Trans. Herts. Nat. Hist. Soc.*, 1883, vol. ii, pt. 3, p. 128.

Ordnance Datum. The water had a temperature of 52 degrees, and the yield was 20 gallons a minute. He also noted another spring a little to the south. Presumably the water of these comes from Drift Gravel.

The spring marked on the map (Herts. 47, but in Bucks.) at Rolls, close to the western boundary of the parish of Denham, on the left side of the Misbourn, must be thrown out of the gravel, presumably by clay of the Reading Beds. Whether this has been affected by the new railway I know not.

Another spring, marked on the same map, east of Pond Cottage, by the south-eastern corner of Bulstrode Park, and in the parish of Fulmer, seems to have a like origin.

Mr. Dickinson noticed many years ago that the village of Abbot's Langley is on "a bed of gravel overlying a natural basin of clay," so that "water poured over the sides of the basin . . . and numerous springs were formed . . . after a wet season, and the springs were invariably dried up in the summer."[1]

U. A. Smith has noticed springs near (just north of) Harpsfield Hall, west-north-west of Hatfield. These must come from Glacial Drift (? gravel). The stream from them is not marked on the old map 46 S.E., though it is on the newer one, 239. On the former it is shown as starting lower down, some way south of Harpsfield Hall. It is one of the head-waters of the Colne.

He also mentions other springs between Ellenbrook and Popefield Farm, which must also come from Drift, and which result in a short tributary to the same stream.

Any shrinkage in these two sets of springs, and they can hardly ever have been of large amount, can have nothing to do with depletion of the Chalk by pumping, as is assumed.

Other springs noted as occurring at Beaumont Farm, eastward of St. Albans, are also presumably from Drift. With regard to this valley, however, R. E. Middleton, in the same volume (p. 555) says that the highest visible source of water "is and has been at Boggy Mead Springs, just north of the Hatfield Road.[2]

Between Colney Heath and London Colney three springs have been noted that must come from Drift gravel. The highest of these I saw at about 330 yards north-north-west of Tyttenhanger Farm. The next is marked on the map (Herts. 35) just below the south-western corner of Tyttenhanger Park, and over 700 yards south-south-west from the house. At the lowest, about 340 yards a little north of east from St. Peter's Church, London Colney (marked on the map, Herts. 40), there was a very small flow when I was there in October, 1904.

The spring about 280 yards east of St. John's Church, by the southern end of Brocket Park, in the parish of Hatfield, and marked on the map (Herts 28, S.W.), seems to rise from gravel, as also does another spring at Stanborough (marked on Herts. 28, S.E.)

By the stream about 660 yards south-eastward of High Leigh, Hoddesdon, a spring is marked on the map (Herts. 36). Its origin seems doubtful, as, according to the geologic map, it is on London Clay, a little below the gravel.

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[1] *Proc. Inst. C. E.* 1885, vol. xiv, p. 71.

[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 390.

A spring marked on the map (Herts. 41) by Broadfield Farm, east of Bury Green, Cheshunt, is from gravel, overlying London Clay.

The spring marked on the map (Herts. 28 S.E.) just south-west of Black Fan, by the border of Digswell parish, in the valley of the Maran, about $1\frac{1}{8}$ miles south-eastward of the church, must come from gravel.

Of the western and shorter head-water of the Beane R. E. Middleton says that "there are land springs at Bedwell Plash (Stevenage) and Broadwater (Knebworth or Shephall), but they have no connection with the chalk water."[1] They are certainly in a Drift-tract; but one cannot say that water may not come up from the Chalk, through the gravel and sand, and the outcrop of the Chalk is near by. In the same volume, p. 622, it is said that "A spring above the National Schoo's (Stevenage) is always running," and on p. 623 springs at or near Broadwater are recorded, as also others at Ridlings Wood (? in the Aston side-valley).

The spring marked on the map (Herts. 22, N.E.), about 450 yards north of Westfield Farm, Little Hadham, must rise from gravel.

BOULDER CLAY.

There are some cases of springs being marked on the maps in a Boulder Clay tract, and probably there are more than at the three places now to be noted.

At Chicheley (Bucks. 5, S.E.) three springs are shown: 1 at Little End, about 650 yards south-south-west of the church; 2 about 390 yards north-west of the same; 3 about 300 yards nearly east of the same.

About 260 yards south-west of the rectory, Filgrave (Bucks. 5, S.W.)

At North Crawley, in the park, about 440 yards south of west from the church (Bucks. 10, N.E.)

Dr. R. L. Sherlock has noted two springs in the grounds of Bramfield Rectory (Herts. 29, N.W.), which are said never to dry.

MINERAL SPRINGS.

There is very little to be said on this subject for either county.

The only noted case in Buckinghamshire is that of Dorton Spa, the water of which presumably comes from Corallian Beds, and it has a small literature. A good description was given by T. Knight in 1833; but the following remarks are taken from a fourth edition, which is much fuller. For an account of the cures, and for a note on the geology of Brill, by W. D. Sault (pp. 77-83), the reader is referred to the interesting original.[2]

"When sinking the lining of the Wells, the soil which was thrown up, had the same peculiar unctuous property as Fuller's earth, yet differing from it in colour; the prysmatic chrystals glistening throughout it, evidenced the quantity of Sulphate of Lime it abounded with; it had also interspersed through it portions of Iron Pyrites and a pale yellow powder, resembling Milk of Sulphur, which, during the hot

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 562.

[2] 'The History of the Dorton Chalybeate,' 1835. Pages quoted, 8–10, 13–16. The last two paragraphs also in the edition of 1833, pp. 12–14.

days it lay exposed, emitted a strong sulphurous vapor. This was found within a foot of the surface and continued to the depth of twelve feet, the whole of the distance they went."

"With respect to the Physical Phenomena, the Dorton Chalybeate has a strong inky taste ; a peculiar but not offensive odour ; it is perfectly clear at the well, but when exposed to the action of sun and air, a slight pellicle (an evidence of gas) appears on the sides and surface of the water, and in a short time, it deposits a light brown sediment . . . which is Oxyde of Iron."

A chemical examination by PROF. BRANDE gave the following result, a pint of the water yielding 25 grains of saline matter :—

Carbonic acid, Nitrogen, Sulphuric acid, Silica ...	Trace
Sulphate of lime	11·5
Muriate of soda	1·4
Sulphate of alumine ...	2·1
Sulphate of iron	10

"Springs of the purest water rise from almost every hill on the estate ; and in the upper grounds of Dorton Park, bordering on the parish of Brill, the attention of the neighbouring villages has been attracted from time immemorial to a stream, issuing from a small orifice . . . by the destruction it occasioned to vegetable life. . . . It was named by the common people in the vicinity the 'Alum Well' ; the taste of this salt being most apparent . . . and the cattle in the neighbouring pastures, being allowed a free access to it, it was observed that those amongst them which laboured under any disease, recurred to its use spontaneously, and rapidly recovered." . . .

"Of late years its fame has been widely spread in the surrounding country. . . . At length the influx of visitors to the Well became so great . . . that it was judged advisable . . . to inclose the Well," and from 50 to 100 gallons of water a day have been supplied to applicants. An ornamental pump-room and baths were built.

SLEIGHT'S work, of 1842, is practically taken from KNIGHT, as far as the water is concerned ; but various cases of benefit from the use of the water are added.

W. W. FISHER gave me the following note in 1916 : The shallow well had been recently cleaned and repaired. About 40 years ago the water was said to be acid in reaction, containing free sulphuric acid. The exact geologic horizon of the water is doubtful. It contains a notable amount of iron-sulphate and carbonate. For a detailed analysis of the salts, by him, *see* p. 271.

In 1876 R. A. PRYOR looked up the records of mineral springs in Hertfordshire,[1] suggesting, in the first place, that a chalybeate spring had been described by mistake as occurring at Watford. There is a record of one at Watton, discovered about 1682, but which has not attracted much attention.

The most celebrated medicinal spring was "on the Common, near Barnet," which was once extensively used.

Others are noticed as "in the common of *Northal*" (Northaw) and at Coffleys (Cuffleys).

[1] *Trans. Watford Nat. Hist. Soc.*, vol. i, pp. 109–111.

Chalybeate waters have been noticed as occurring at Welwyn "at the corner of the rector's garden," and at Hitchin "in the Sun inn yard."

Besides these there are also noted "petrifying Springs in the grounds of *Broadfield*, and in the Parish of *Clothall*."

Mr. Pryor says, "All alike have now dropped out of general notice, but of several the local tradition must yet survive."

Of the spring on Barnet Common we have a record by the Rev. W. M. Trinder, from which the following remarks on the water are taken.[1]

"In the year 1800 it was slightly sulphureous both in smell and taste, till the vapour, by standing in the open air, had exhaled."

"The water strains through a clay into the well, which is encompassed by a brick building. . . . The water is of the ordinary colour . . . its taste is somewhat brackish, but by no means disagreeable." For an analysis, *see* p. 275.

In the *Westminster Gazette* of September, 1918, there is a notice of "Barnet's Physick Well," which is "in a field at the far end of Wellhouse lane, half a mile to the west of the church. All that marks the spot to-day is a rusty iron pump, some three feet high, in the middle of what was a grass field . . . turned into a potato patch."

[1] 'The English Olive-tree . . .' etc., 1812. Pages quoted 63, 65.

BOURNES.

GENERAL DESCRIPTION.

The term Bourne is, of course, really only another name for a brook or stream ; but it has often been restricted of late years to those streams (fed by springs) which are intermittent, that is to say, whose point of origin varies greatly, at one time being a long way down in the valley, at another at a very much higher point.

Strictly the word should be used with a prefix, such as Nailbourne, as in Kent, or Winterbourne, as in Wiltshire. Other names, too, exist, Lavant being used in parts of Hampshire, and the appropriate term Gypsey, which implies a wandering character, in Yorkshire.

The more or less sudden outflow of water along a tract that is usually dry has naturally had a fascination for the inhabitants of the invaded district, and not unnaturally these outbursts have been regarded as an omen of evil, and the names woe-waters or woe-meres given to them.

Such occurrences have been recorded for some centuries, as may be seen from a paper by B. Latham in which a historical account of observations is given,[1] starting from 1472, in which year bournes seem to have abounded. The following remarks, relating to 1472, 1473, are taken from Latham's paper, and were got from Dr. J. Warkworth's "Chronicle" (published by the Camden Society in 1839).

"Womere watere ranne hugely, with such abundance . . . that never manne sawe it renne so moche afore this tyme. Womere is callede the woo watere : for Englyschmen, when thei dyd fyrst inhabyde this lond, also sone as thei see this watere renne, thei knewe wele it was a tokene of derthe, or of pestylence, or of grete batayle ; wherefor thei called it *Womere* . . . for alle that tyme thei sawe it renne, thei knewe welle that woo was comynge to Englonde. And this Wemere is vij myle frome Sent Albons, at a place callede Markayate ; and this Wemere ranne . . . nevere so hugely as it dyd this yere, and ranne stylle to the xiij day of June next yere folowynge. Also ther has ronne dyverse suche other wateres," of which examples are noted.

This wrong idea, of the connection of bourne-outflows and disasters, was satisfactorily disposed of more than 100 years ago, in a note on the Croydon Bourne, as follows : "The fact is, that in a wet summer (? winter), without any alteration in Church or State, a bourn rises."[2] Nevertheless, I fear that even in these more enlightened times this and other absurd views are still held by many people. Presumably they would point to the fact that bournes have flowed during the years of our great war, in answer to which one may point out that they also flowed in the two years before the war as well as in other years from 1897 on, when no great disaster happened.

It was to be expected that peculiar theories of the origin of these periodic outbursts of water should be started ; but the subject is now well understood, and we know that bournes are caused merely by the

[1] 'Croydon Bourne Flows, 1904.' Also issued with the *Proc. Croydon Nat. Hist. Soc.*, vol. vi.

[2] Manning and Bray, History of Surrey, vol. ii, p. 362 (1809).

rise of the underground water-level or plane of saturation, after a wet season, until it reaches the surface in the lowest grounds, when, of course, what was underground water becomes overground.

BUCKINGHAMSHIRE.

The only published record of bournes in this county that I have been able to find is in a Note by J. Lucas,[1] in which the Loudwater and the Misbourn are referred to. His remarks are not wholly concerning bournes, but deal also with ordinary springs : it is, however, convenient not to separate them. He takes the occurrences noted in an up-stream direction, whereas in other cases what seems the more convenient downward arrangement is followed.

The Wye or Loudwater.

Of the West Wycombe branch of this stream we have no records of intermittent flow. Of the Hughenden branch, which is in Middle Chalk, Lucas remarks as follows (p. 371) :—

"For just over $\frac{2}{3}$ mile above the perennial springs at the parliamentary boundary of High Wycombe, the bed of the Hughenden stream, running on alluvium half way and gravel the other half, was dry August 31st, 1885. The next 730 yards, along which the gravel is exceedingly narrow or absent, extending from the angle between two ponds close to the road east of Hughenden Manor House to Church Farm, was in water, and was fed by two springs of clear water both on the east side, besides that at Church Farm, on which a little well has been sunk 7 ft. 6 in. deep. Above this point the gravel widens out, and the deep dry channel of the stream continues for $\frac{2}{3}$ mile, or [to] just above Bottom Farm, where are three dry spring-heads in a low-water period, besides two others in the meadow below. There (? these) five dry spring-heads are all on the east side of the valley ; thus proving that when there is water in the bourne-channel it enters from that side. The low-water contours show that it comes from the north-east."

Since the publication of Lucas's Note R. L. Sherlock has observed that "in unusually wet seasons the Hughenden brook flows as high as the Harrow Inn," more than a mile above Hughenden Church.

Speaking of the stream generally Lucas says (pp. 372-374) :— "the Loudwater is fed from both sides (by springs) down to the 180 ft. contour, and only from the north (north-west or left) side from Loudwater to Glory Mill. Moreover, there are no springs on the south (south-east or right) side below High Wycombe. There must, therefore, be more water in the River Loudwater above Loudwater than there is at Woburn (Wooburn), as has, in fact, been proved by the gaugings of Mr. Baldwin Latham."

The Misbourn.

Of this stream Lucas writes as follows, again working upward (p. 370) :—

"North of the perennial spring at Chalfont St. Peter, which issues in a meadow west of the dry river-channel the Misbourn . . . . for the next six miles at least, or as far as Shardelowes Lake and probably further . . . runs in a channel upon an impervious

[1] *Surveyors' Institution. Professional Notes*, vol. xiv, 1907, pp. 370–374.

alluvium which suspends, as in a gutter, the water from the upper perennial spring at Little Missenden Abbey to the point where it gradually sinks, about ¼ mile above the junction of its channel with the waters from the lower perennial spring at Chalfont St. Peter. The channel of the main stream above the spring stream, including the then dry mill-pond at Chalfont St. Peter, was dry for this ¼ mile, May 24th, 1884; 1½ mile higher up, at Chalfont St. Giles . . . the well in the garden of the Merlin's Cave P.H., close to the stream, gave water level . . . 12 ft. 6 in. below the river, September 25th, 1885."

"Half a mile higher up, just below Chalfont Mill, a well on the *very edge* of the river, 15 ft. 6 in. deep, and whose mouth was 3 ft. 4 in. above the stream, was dry . . . while three months earlier it had 6 ft. of water in it."

"The whole distance from Chalfont St. Peter spring to Little Missenden Abbey spring the flow of the subterranean water is across and under the Misbourn Valley from west to east."

The Chess.

For the following notes on this stream we are indebted to J. Hopkinson, who fortunately did not confine his work to Hertfordshire.

It is said that many years ago a stream was seen to flow down Chesham Vale (the northern branch of the valley), and the same was the case in 1904, after the heaviest rainfall recorded in any year in Herts., and probably the heaviest in Bucks. As the only year within our records with a rainfall nearly approaching that of 1903 was 1852, most probably 1853 was the year of the early flow referred to.

In April, 1916, there was a continuous stream down the valley from a short way above the junction of the roads from Tring and Wigginton for three miles, to Chesham, where it flowed into the permanent river Chess. The road down the valley was in many places completely under water, and the meadows west of the road were flooded, in at least the upper part of the valley, from a little below the point where the stream rose. C. Oldham tells me that the like occurred again in 1919.

The Hertfordshire Bourne (the account of which follows) is also in part the county-boundary of Buckinghamshire.

THE HERTFORDSHIRE BOURNE.

Perhaps, after the Croydon Bourne,[1] this little intermittent stream (in a short tributary-valley of the Bulbourne), which is usually described under the above name, has the next largest literature, although this starts only in 1853, with a short note, and with nothing more until 1877. This is owing, of course, to the persistence of the Hertfordshire Natural History Society in visiting the valley and in recording the outflows of the water, a class of work for which such Societies are well fitted.

Like the Croydon Bourne, this starts in Middle Chalk; but whereas with the former, as the head-waters go further back, up the valley,

[1] *See* 'Memoir on the Water Supply of Surrey,' 1912, pp. 68–77, 337, 338.

lower beds are reached, and possibly at the highest part, the water rises from the Lower Chalk, in the Hertfordshire case, as the stream starts further up the valley, it comes from higher beds, and perhaps at last from the Chalk Rock.

According to an account of an excursion made in 1881,[1] "There is no historical record of the flowing of the Bourne in olden times (though it is mentioned in Camden's Britannia). Our county historians . . . do not allude even to the existence of such a stream.

"The earliest notice of the Hertfordshire Bourne appears to be so recent as 1876," by Sir J. Evans (published 1877). But this was really preceded by the Rev. J. C. Clutterbuck, in 1853.[2]

"Although historical records thus appear to be wanting, the valley of the Bourne furnishes evidence, in the extensive denudation which has resulted in its formation, of the existence of a stream most probably long before historic times. For five miles from the point where it flows into the Bulborne, this stream, in its occasional appearance above the surface, has cut a valley of considerable depth and at least a mile in width, through the glacial gravel and sand, and the clay-with-flints, into the Chalk which forms its bed. That it ran in olden times is also proved by its now forming a county boundary for a considerable part of its course." Curiously enough, however, the lowest part of the course, which is the most often a stream, is only a parish-boundary.

This bourne therefore belongs to Buckinghamshire in part, and not wholly to Hertfordshire.

One may note here that on this excursion Prof. Attfield took a sample of the water at its then source, in a meadow a little west of Harcsfoot Park, for analysis, and found that "it was the ordinary Chalk-water of the district," its contents, in grains per gallon, being chalk 12 ; calcareous matter, in about equal parts of chlorides, nitrates and sulphates, 4 ; saline substances a little over 1 ; and the merest traces of vegetable matter. Later analyses are given on pp. 76, 77.

It is pleasing to find that the first detailed account of this bourne comes from Sir John Evans, who did so much work for Hertfordshire, especially in the matter of underground water, and so to be able to give a description of it from his paper,[3] which also contains general remarks on the subject of bournes, as illustrated by this bourne.

The "Bourne Gutter" (of the Ordnance Map) joins the river Bulbourne, at the hamlet of Bourne End, about two miles below the town of Berkhampstead, and "travellers along the high road . . . may pass over the spot where its course traverses the road, without having the slightest idea that a moderately-sized brook occasionally flows there, and that, according to tradition, a man was once drowned at the end of the usually dry culvert which passes under the road . ."

"If we take the inclination of the rivers flowing past Watford and St. Albans, we find that they have an inclination of about 12 ft. 6 in. to the mile in the lower portion of their course, and 18 ft. 6 in. in the upper portion. That shows what is the amount of impediment to water passing through the Chalk in a lateral direction. For, assuming that water could find its way through the Chalk at a less inclination than

[1] *Trans. Herts. Nat. Hist. Soc.*, 1882, vol. i, p. lix.
[2] *Proc. Ashmolean Soc.*, vol. iii, p. 5.
[3] *Trans. Watford Nat. Hist. Soc.*, 1877, vol. i, pp. 137–140.

12 ft. 6 in. to the mile, these rivers would cease to flow, or at all events you would never see the streams upon the surface. The Chalk being porous and pervious, unless there were a sufficiently saturated bed beneath the river to hold the water up at an inclination at least equal to that of the river, it would die in its bed and disappear. The inclination of subterranean water passing through Chalk must therefore be at least 12 ft. 6 in. or thereabouts to the mile in this district."

"In certain years the subterranean water is raised in the body of the hills, and this valley, cut at right angles or nearly so to the main stream, intersects the general surface of the plane of saturation, and the water appears on the surface. It, of course, is not the case that the slope of any valley is absolutely in one uniform line; generally speaking there are some small undulations. In looking at the Bourne, I found this theory of intermittent streams being due to the intersection of the plane of saturation very prettily illustrated, because in one place I found the Bourne running, and when I arrived at a certain spot it had disappeared; further on it ran again, and again disappeared. The plane of saturation was more even than the surface, and where there was an elevation of the surface the water found its way underground instead of running over it." Thus "while the water was visible near Harratt's End (Harriottsend) Lane, it disappeared further down the valley. Past Bottom Farm the water ran in considerable volume, but before it arrived about half-way to Bourne End it disappeared," again to flow lower down.

"Finally he alludes to the connection between rainfall and the Bourne. The first occasion on which he noted the outflow was in March, 1853, and "during the six winter months of 1852 and 1853 there had been through our gauges for ascertaining the amount of percolation, 10·74 ins. of rain," thus "during that winter a much larger quantity of water than usual found its way into the Chalk, for the average winter percolation is not more than five or six inches." Taking another year of outflow, "the Bourne was flowing on February 16th, 1873. The amount of rain which during the six winter months found its way to the subterranean reservoir was 11·25 inches. This year (1876) the Bourne did not commence flowing until April . . . and its appearance is due to a less amount of infiltration of water than usual. There had only been, during the six months ending the 31st March, about six inches, and in April another half-inch of rain, which passed down through three feet of soil. That is rather a small amount of rain to enable the Bourne to flow; but when we look at the amount of rainfall there has been for some years, I think that the reservoir has not been at so low a level when the infiltration commenced, as on some other occasions, and although generally speaking the flow of the Bourne is connected with the amount of infiltration of water during the six months or so preceding, yet we must take into account the state of the springs and subterranean reservoir during the previous years."

Since that time this Bourne has been often visited, notably by members of the Hertfordshire Natural History Society and of the Geologists' Association, and I have had the pleasure of being amongst them. Naturally, therefore, it has been described at various times, as may be seen from the Bibliography (pp. 338–342), one notice having been alluded to above. Such remarks as are additional to Sir J. Evans's account will now be noticed. They are the result of the

untiring zeal of JOHN HOPKINSON in investigating and recording what happened in Hertfordshire.

In a paper of 1899[1] he alludes to the irregular intervals between outflows. After 1873 the Bourne "flowed much more frequently up to the year 1883, during the wettest period in our Hertfordshire record, from which time fourteen years elapsed before it again flowed this year." (1898).

The point of outburst varies also, at one time about a mile up its valley, at another two miles, and sometimes higher. When rising at "low points the plane of saturation of the Chalk was evidently only slightly raised above its normal height . . . but when rising at the highest point, the highest on record being in the third field above Harratt's Lane End, this plane must have been much more raised. . . . Then the stream would probably be augmented by springs at each point lower down its valley where it has risen at any other time, for if springs ooze at these points when the plane of saturation was less inclined, they would surely continue to rise when the inclination was increased."

"The Bourne usually commences to flow between January and April, frequently some time after the rain which causes it to flow has ceased, this interval being occupied by the water which falls upon the surface of the ground percolating through the Chalk to the normal plane of its saturation, which has to be raised to a greater angle with the horizontal than that of the bottom of the valley. . . . The inclination of the valley of the Bourne is from about 15 ft. to the mile in its lower portion to 20 ft. near its head;" but these figures differ from those given later.

"The Bourne has certainly flowed ten times during the last half-century, and in twelve years during this period the mean rainfall in Hertfordshire has exceeded 30 in. The Bourne has never flowed when less than this amount of rain has fallen . . . only twice has it failed to flow when the year's rainfall has exceeded 30 in.," perhaps only once. Somewhat different figures, however, were given later (*see* p. 76).

He gives tables of the rainfall for periods preceding Bourne-flows, and these show "that the Bourne has never flowed, so far as we know, unless there has been an excess of at least $4\frac{1}{4}$ in. of rain in the year, all due to the winter's fall (1896-97); of at least $5\frac{1}{3}$ in., of which the winter's excess was 2 in. (1859-60); or of at least $6\frac{1}{2}$ in., of which the winter's excess was $1\frac{1}{3}$ in. (1878-79)." This subject is worked out in great detail.

"The catchment-basin of the Bourne is at least five square miles in area . . . On the 24th of April, 1897, the flow was about one million gallons a day."

In 1911 HOPKINSON gave an elaborate account of the Bourne, with a plate (two photographic views),[2] which leads one to hope that all future outflows will be duly recorded by the camera. This paper gives practically all details.

"The height of the ground above mean sea-level (Ordnance Datum) at the head of the valley of the Bourne, between Marlin Farm and Woodcock Hill, is about 550 ft.; at Bourne End it is 300 ft.; giving

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. x, pt. iii, pp. 75–81.
[2] *South-Eastern Naturalist*, pp. 10–19.

a mean gradient of 50 ft. to the mile for the whole course of the valley; but for the first half mile from Bourne End the gradient is only 20 ft. to the mile, for the first mile 25 ft.; and for the first two miles 30 ft. . . . the gradient increasing up the valley until near its head, for it gradually decreases in the last mile."

"There are several subsidiary valleys on the south . . . there is also one on the north. . . . These . . . are steeper than the main valley, and . . . there is no record of water ever having flowed down them."

The following is a record of the Bourne-flows :—

1853. Source on March 23, upper end of field above the culvert at White Hill, about 2½ miles up the valley.

1860. Overflowed banks in garden opposite Bourne End Mill.

1866. No record. Flow assumed from the rainfall.

1873. Source on February 16, in third field above White Hill culvert, between Harriottsend Farm and Ashley Green, about 3 miles up the valley. In considerable volume.

1876. Began about the end of April. Source on June 8, about 70 yards north-east of White Hill, a little more than 2 miles up the valley. Flowing with moderate force. Flow not continuous.

1877. Began at Bourne End, a furlong up the valley, 6 January. Source on January 28, as in February, 1873.

1879. Source on February 16, close to White Hill, nearly 2¼ miles up the valley. Ceased running at Bourne End May 21; started again May 28; finally ceased December 19.

1881. Began early in March. Source on May 7, in a meadow west of Haresfoot Park, 3½ miles up the valley. Pools in the fields above White Hill, but no continuous current.

1883. Began at Bourne End on January 9. Increased in volume until the beginning of February. Source on April 21, about the same as in May, 1881; but a continuous current from there.

1897. Began at Bourne End near the end of March. Source on April 24 about ¼ mile lower down than in 1883. Stream flowing freely to White Hill. Lower down the stream here and there widened out into pools. Rate of flow estimated at about 2,000,000 gallons a day.

1903, 4. Began at Bourne End on 15 November. Ran continuously from its source about 3 miles up the valley on 1 January. Reached its greatest volume about the end of February. Ceased by the end of July.

"It is possible, but not probable, that the Bourne flowed in 1869 without its flow having been recorded. It is not likely that any flow has escaped notice since the foundation of the Hertfordshire Natural History Society in 1875."

In May, 1912, Hopkinson read yet another paper on the Bourne, called forth by a fresh flow, from which one must quote.[1] "It may seem strange that a river which did not flow during a long period of heavy rainfall should rise some time after that period had ceased and should attain its maximum volume after a month of unprecedently dry weather, but this has just happened in the valley of the Hertfordshire Bourne. The rainfall in the neighbourhood in the six months of the past winter (October to March) has only twice been exceeded during the last sixty years, yet the Bourne did not flow while this wet period continued; on the other hand such a prolonged drought as we are now experiencing has only once before been recorded during that long time, yet the Bourne was at its height only a few days ago, after this drought had lasted for more than a month."

[1] *Trans. Herts. Nat. Hist. Soc.*, 1913, vol. xv, pt. 1, pp. 67–70.

"It is therefore evident that, unlike rivers on impermeable strata which are replenished by surface-water and are highest very soon after the rain on which they depend has fallen, our Bourne is fed from an underground source, a permeable rock saturated with water, and that the rain . . . does not immediately replenish that underground reservoir, but sinks down to it . . . very slowly."

"It is when rain adds to the reservoir of supersaturated chalk more rapidly than the water can percolate downwards and along the normally very slight inclination of its surface that the gradient of that surface . . . increases."

"The plane of saturation follows to some extent the inclination of the ground, being highest at the head of our valleys and lowest at the foot; when the rainfall is not excessive it varies from about 12 to 15 ft. to the mile in the Middle Chalk and from about 15 to 20 . . . . in the Upper Chalk."

"The Bourne has never been known not to flow when the rainfall in the neighbourhood has exceeded 32 in. in the year ending 31st of March, and it has never been recorded to have flowed when it has been less than 32 in. Within the period of our record of 60 years the smallest rainfall which has been known to cause it to flow before the present occasion was 32·44 ins. . . . in the year 1896-97; the largest which has not caused it to flow was 31·90 ins. . . . in the year 1909-10; but . . . only twice before in our 60 years' record has the rainfall in the neighbourhood in the six winter months been so great as it was last winter. . . . Although last year's rainfall is the smallest, by less however than half an inch, which is known to have caused it to flow, it must not be overlooked that it is in the winter that by far the greatest amount of the rain . . . percolates into the Chalk."

"The flow of the Bourne on this occasion has only extended from a short distance above the foot of White Hill to about a quarter of a mile above Bourne End. It commenced to flow on Good Friday the 5th of April, reached its height on Sunday the 5th of May, and is now gradually declining."

The Bourne again started in 1913, and was duly visited by the Hertfordshire Natural History Society.[1] It "commenced to flow near the end of February, attained its maximum about a month later," and then decreased. Presumably it was a small flow.

W. T. Burgess took a sample of the water of the flow of 1913, from an old gravel-pit on May 11th, and has communicated the following analysis, in parts per 100,000 :—

Total solid residue	34·56
Ammonia, free	·009
Ammonia, albuminoid	·004
Nitrogen as nitrates	·422
Nitrogen as nitrites	0
Oxygen absorbed in 4 hours, at 80° F.	·020
Chlorine	1·35
Total carbonates, calculated as carbonate of lime ...	24·8

Hardness, total (by soap-test) 26·6; permanent 4·; temporary 22·6.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1915, vol. xv, pt. 4, p. xxxviii.

There was a flow in 1915 and a longer one in 1916, both of which have been recorded by HOPKINSON,[1] and I had the pleasure of seeing the latter with an excursion of the Hertfordshire Natural History Society on April 29th, when it had begun to decrease; but was still flowing strongly and I took the following notes. The stream started in a shallow pool, on the Buckinghamshire side of the county-boundary, about 840 yards northward of "The Banks," an old moat at Grove Farm, and formed a continuous stream thence downward.

Along the meadows from a little below the starting point, down to Bottom Farm, there was a nearly constant oozing out of water a little above the channel, on the Hertfordshire side, and presumably the like occurred on the Buckinghamshire side. Much additional water was thus contributed to the stream.

The reason for the starting point, the highest which any one had seen, seems to be that it is at the meeting of two arms of the valley; but MR. HOPKINSON told me that the water was said to have risen somewhat higher. This must have been after a very wet season.

On the above occasion DR. A. E. BOYCOTT took two samples of the Bourne-water. That from the lower end yielded 100 milligrammes of calcium per litre, and that from just below the highest point 102. This, he says, is just about the figure for the Colne about Munden, and a good deal less than that of London tap-water, or the Thames. He suggests that possibly this may mean that a fair amount of the Bourne-water is surface-drainage.

The account of the flow of 1917 is the last from the pen of JOHN HOPKINSON and was not published until after his death. In speaking of the periods between flows, and alluding to the common idea as to seven years, he says, "fourteen years have elapsed without a flow, while for the first time on record, owing to the heavy rainfall in recent years, it flowed this year for the third successive year"; but the flow, which started early (in February), lasted for only a short time.[2]

It is sad to think that, unless he has left any notes for 1918, we shall have no further account of the Hertfordshire Bourne from that zealous observer. But we may hope that his example may result in such work being taken up by other Hertfordshire men. The years 1918 and 1919 were also bourne-years, and amongst others the Hertfordshire bourne has been active.

OTHER HERTFORDSHIRE BOURNES.

The Bulbourne.

The top waters of this stream are intermittent. The highest recorded point of rise is opposite the canal-lock (at Cow Roast ?), some 1,200 yards above Dudswell (? in 1883), whereas in March, 1891, there was no flow above Northchurch, and in September, 1891, the river-bed was dry down to East's timber-yard, Berkhampstead, a difference of over three miles. Later (? in 1892 or 1893) the source went up again to Dudswell.[3]

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[1] *Trans. Herts. Nat. Hist. Soc.*, 1916, vol. xvi, pt. 2, p. 108, and 1917, pt. 3, pp. 169–172.

[2] *Ibid.*, 1919, vol. xvii, pt. 2, pp. 97, 98.

[3] U. A. SMITH and R. E. MIDDLETON. *R. Comm. Metrop. Water Supply. Appendices*, 1893. pp. 401, 548.

The Gade.

Sir J. Evans recorded the following changes in the point of outflow of the Gade, many years ago :—

"On the 19th April, 1853, there were 26 ft. of water in the well at Mile Barn . . . 5 miles to the N.W. of Hemel Hempsted, and the source of the river Gade was . . . about 600 yards to the S.E. of the well, although earlier in the year it had been 200 yards to the north of Mile Barn. . . . At the present time (early in April, 1855) the well . . . was dry, and the Gade rose two miles and-a-half lower down the valley, than its ordinary source during the period of full water."[1]

U. A. Smith says that the Gade formerly rose as far up the valley as Mile Barn, $2\frac{1}{2}$ miles above Great Gaddesden, whilst "in the early part of the summer of 1890 its source was in meadows . . . about one mile above Gaddesden, but in March 1891 . . . there was no trace of any water more than 400 yards above Gaddesden, and here it was only a mere dribble." From personal inspection, R. E. Middleton doubts if the source "was ever higher than 500 yards below Mile Barn," though "in times of very heavy rain there is water on the land as high as Mile Barn."

"There are not . . . any springs . . . near Mile Barn, but when the level of saturation is very much raised by excessive rainfall, it overflows the low-lying ground and remains there until the water level in the chalk and gravel is lowered."[2]

The Ver.

Sir J. Evans has said, "I have known the source of the little river Ver to be at least five miles farther up the valley in one year than in another."[3]

According to U. A. Smith, "The river not many years back took its rise partly to the north-west of Kensworth Lynch . . . and partly to the north," the valley forking here. "In June 1891 . . . from these points down to Redbourn . . . was absolutely dry"; but (? in 1893) the source went up "to a point above Friars Wash" (Flamstead).

R. E. Middleton adds that "the bed of the stream, like that of the River Gade, has a gradient which is only a little steeper than that of the dry weather line (plane) of saturation in the chalk-water system, and a comparatively small reduction of level in the water, and consequent flattening of the gradient in that system, serves to dry a proportionally extensive length of the river." He held that the Ver never rose at or above Kensworth Lynch "except in 1883, and at some previous period of equal rainfall of which there is no record."

The Church End branch-stream, at Redbourn, U. A. Smith says, "formerly rose at two places to the west of St. Mary's Church," but now the water-course is dry. "There has been no flow from the

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[1] *Proc. Inst. Civ. Eng.*, 1855, vol. xiv, p. 87. In discussion.

[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, pp. 399, 550. *See* also p. 586.

[3] *Proc. Inst. Civ. Eng.*, 1885.

springs beyond Church End for twelve or fifteen years."[1] It is perhaps to this branch that the following old note refers.

Redbourn, according to CAMDEN's "Britannia," is remarkable "for a brook in its neighbourhood named *Wennier*, which the common people believe never swells or rises without presaging scarcity or some misfortune." GOUGH adds, "the brook . . . is called *Womer*, and . . . *Woborne Mere* . . . the brook or mere of woe. . . . Norden fancies the neighbouring *Market street* hath its name corrupted from *Mer-gate* . . . an issue or out-gate of water."[2]

Of this stream J. HOPKINSON wrote to me, in May, 1904, that it was flowing copiously past Redbourn Church and through the frequently dry places on the southern side of Redbourn Green into the Ver near Watling Street.

The Colne.

At the end of his paper on the swallow-holes HOPKINSON says, "The extent of variation of the source of the Colne is about 15 miles, from near Barnet Gate, midway between Chipping Barnet and Elstree (Middlesex), to a few field-lengths above Colney Street, where I have seen the river rise in a very dry year."[3] As this place, south of St. Albans, is only just above the junction with the Ver, it follows that practically the whole of the head-water of the Colne is an intermittent stream. But it should be noted that the highest points of the Colne are dependent chiefly on surface-drainage, so that this river is not a bourne in the same way as the rivers whose beds are on bare or thinly gravel-covered Chalk.

For the description of a very unusual flow along a northern tributary of the Colne, which is almost always a dry valley, we are indebted to J. HOPKINSON, who wrote to me on the subject in 1916, and has since printed the following account: "There has not been, for the last 40 years at least, such a flood in the Sandridge valleys . . . as there is at present (April 1916). The road from Sandridge to Hatfield is impassable between Sandridge and Sandpit Lane by motor-cars, and . . . in one stretch of flooded road nearly a mile in length which I attempted to wade through, the water became so deep, reaching to my knees, that I had to give up the attempt and take to the fields, which also were under water. In the higher part of the valley, above Sandridge, the water had gone down considerably, but not so much that houses on the road-side, vacated owing to the flood, could yet again be inhabited. . . . I am informed that the village of Sandridge was flooded, though not to such an extent as at the present time, about fifty years ago. This must have been either in 1860 or 1866, most probably in the earlier year."[4] DR. A. E. BOYCOTT tells me that he had a like experience in trying to get through on a tricycle.

In writing of the lower part of the above flow MR. HOPKINSON says that from the width of the stream and from the rapidity of the current it was clear that the stream had been augmented below Sandridge, and he adds that at the junction of the road to Hatfield with that to Cooper

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, pp. 403, 551. *See also* pp. 587, 593.
[2] Remarks taken from *Trans. Herts. Nat. Hist. Soc.*, 1882, vol. i, p. lix.
[3] *Trans. Herts. Nat. Hist. Soc.*, 1892, vol. vi, pt. 7, p. xxxii.
[4] *Ibid.*, 1917, vol. xvi, pt. 3, p. 172.

Green (north-eastward), the ditch leaves the road and becomes the bed of a brook in the fields, usually dry, but then with a good flow of water, to the Smallford tributary of the Colne. The roadside-ditch is clearly meant to carry off surface-water, after heavy rain ; but it was inadequate to take the water rising from the Chalk.

The Mimram.

U. A. SMITH says, "This river still rises at Stagenhoe Bottom, to the north-west of Whitwell (in the parish of King's or St. Paul's Walden), but the springs constituting its source are much weaker than formerly."

R. E. MIDDLETON adds of this branch of the valley, "An examination of the ground shows that there is a considerable collecting area, extending for $3\frac{3}{4}$ miles above Stagenhoe Bottom to Lilley Village, but that there is no defined watercourse, and that in fact the level of the subsoil water is, except in seasons of quite exceptional rainfall, below the surface of the ground. Such a period of excessive rainfall appears to have occurred about 1882-83, when the water formed a channel for itself down to Stagenhoe Bottom, and overflowed from a gravel pit . . . some distance above the sources of the river and which generally contains some water."

"A similar flow . . . appears to have occurred once previously within the memory of man."[1]

The Beane.

U. A. SMITH says : "The main stream formerly had its origin at various points from one mile to five miles north of Walkern, extending over a district bounded by the villages of Weston, Rushden, and Cottered. The small streams draining this district are partly supplied by surface water (from the Boulder Clay) . . . in the summer of 1891 the stream was dry for some five miles or more below its original source."[2]

R. E. MIDDLETON says (in the same volume, p. 563) : "The river was dry down to Frogmore in or about 1868."

Of the Stevenage branch, which, however, seems to get most of its water from Drift, R. E. MIDDLETON says : "The stream is said to be dry every summer above Oaks Cross Farm" (Aston), westward of Frogmore.[3]

The Quin.

Of this stream, a tributary of the Rib, R. E. MIDDLETON notes : "It is said that it rises in (? around) Biggin Moor, that the water loses itself (underground), and reappears a short distance above Quinbury Farm, above Braughing ;"[4] so that we may have here something in the nature of a bourne.

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[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, pp. 408, 560. Also pp. 616, 617.

[2] *Ibid.*, p. 409.

[3] *Ibid.*, p. 562.

[4] *Ibid.*, p. 565.

The Ash.

U. A. Smith has said : "About five years ago the River Ash had its rise at Albury, and flowed continuously winter and summer from that point. It now (1891) rises between Little and Great (Much) Hadham, more than two miles lower down."[1] On the Ordnance Map the stream is marked much higher, to above the village of Brent Pelham, but there it is the result of the drainage of a tract of Boulder Clay, and it is not until reaching the northern border of the parish of Furneux Pelham that the Chalk crops out, in the bottom of the valley. It seems therefore that we have here a bourne, from Furneux Pelham down to Little Hadham.

In closing this account of the interesting subject of intermittent streams one cannot but wish that the other Chalk-streams had received half the attention that has been given to the "Hertfordshire Bourne," and that the Hertfordshire Natural History Society will be able to do for the former what it has so well done for the latter. It is only the members of a local society, resident at or near the various sites, that can make proper records, over a long time. The officers of the Geological Survey can only note what they see at the time of their work.

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 410.

SWALLOW-HOLES.

GENERAL ACCOUNT.

As springs are the appearance of underground water at the surface, so swallow-holes are the disappearance of surface-water underground, Where springs occur in a water-course, these may, under certain conditions, be inverted, as it were, and turned into swallow-holes. In like way, perhaps, swallow-holes may be turned into springs by the rise of the saturation-level in the Chalk.

The sudden disappearances of streams may occur in any limestone-tract, where there is a fairly broad outcrop of a fairly thick mass, and even, under favourable conditions, where a comparatively thin limestone has a comparatively narrow outcrop. Both of these occurrences are conspicuously shown in various districts of the Carboniferous Limestone, which, being a hard and often massive jointed rock, gives rise to swallow-holes of a very marked kind.

Our Chalk, too, often shows the like thing in a marked way, some of the swallow-holes in it being distinctly funnel-shaped, with streams running down them, though in others there is only a slight hollow into which water flows, but out of which it does not go. Hertfordshire is especially notable in this matter, and one of its sets of swallow-holes is well known to geologists, having been often visited.

As some of our springs are intermittent, so also are most of our swallow-holes, as they depend wholly on the water flowing over the surface to them, and in clay-tracts the small streams usually dry up in summer.

The earliest systematic account of swallow-holes that I have seen refers to those of Hertfordshire, and was written by that very good observer the Rev. W. H. Coleman, who remarked as follows :—In those "places, where the clay capping the ridges has a greater thickness, small brooks are formed upon the uplands which have water in their beds most part of the year ; but these streams seldom reach the main rivers, except in winter, and many of them not at all, their waters being absorbed into the chalk through funnel-shaped basins locally termed 'swallow-holes.' Examples of these may be seen at Mimms-street, where the nascent Colne is lost in ordinary weather ; at Hatfield Parsonage ; in Hatfield Park ; in Sherwood's (Sherrards) Park, Digswell ; and between Hertford and Bramfield (in a Drift-tract), where the brook which anciently flowed past Broad Oak End and Goldings, to the Beane is now lost a mile or two from the river. The waters absorbed do not, we presume, make their way in one channel beneath the earth, and gush up again in the form of springs, as some suppose. Were this the case, the springs would run more strongly shortly after rain, and at such times their waters would be turbid like those of the brooks. We rather suppose that the water is dispersed and gradually settles through the chalk stratum till it reaches the plain of saturation of the chalk, up to which it is constantly charged with water. This plain of saturation is apparently a little above the level of the water in our rivers, and inclined to the horizon from south-east to north-west, at much the same angle as the general level of the surface."[1]

[1] 'Flora Hertfordiensis' (Webb and Coleman), pp. xlii, xliii, 1849.

This work has been quoted by HOPKINSON, in Prior's Flora of Hertfordshire, 1887, and, as far as I know, it gives the only notice of the swallow-holes on the Digswell (or Ayot) Tertiary outlier and in the Drift-tract just north-west of Hertford.

PRESTWICH, however, seems to have been the first to notice definitely that swallow-holes occur at or close to the junction of the Tertiary beds and the Chalk, in a paper "On some Swallow Holes . . . near Canterbury,"[1] in which he gives a general section across those formations that would serve equally well for Hertfordshire, and remarks, in his concluding paragraph, "It would appear that two conditions are essential for the formation of swallow holes: the one, that there should be streams formed at such a level that they have to pass over a surface of country higher than that of the main valleys of drainage; and the other, that the line (plane) of water level in the mass of calcareous strata in which the swallow holes are formed should be below the level at which the streams drilling the swallow holes are absorbed. . . Consequently wherever a predisposing cause, such as a crack or fissure, may exist, the water will tend to escape through any available subterranean channels to the lower water-level and then to the river-channels, in lieu of flowing over the surface to the same ultimate point."

The application and extension of this view to the northern escarpment of the Tertiary beds in the London Basin was made seven years later[2] in a Geological Survey Memoir dealing with two counties contiguous to those with which we are concerned. In this, as in other matters, I have had the honour of following in the footsteps of PRESTWICH.

In 1864 those swallow-holes that had been observed in the parts of the two counties shown on Sheet 7 of the Geological Survey Map were noticed in the Memoir on that map, and in the same year the REV. J. C. CLUTTERBUCK made a short reference to the swallow-holes of Hertfordshire,[3] and the one particular occurrence that he records seems to have escaped notice in the above-noted Memoir. He says: "Very remarkable instances of this natural drainage may be seen more or less along the outcrop of the sand beds of the Plastic clay formation (Reading Beds) in the parishes of Bushey and Aldenham," and he specifies those in the stream from the Elstree reservoir (*see* farther on).

The description in the Memoir of 1864 was repeated in 1872, and again in 1889,[4] probably with additions, and in 1893 these scattered notes were codified in a Memorandum on Swallow-holes in the Chalk of the Thames Basin.[5]

The whole of these accounts are now reproduced, with additions from various sources. It should be understood that my notes, published in Geological Survey Memoirs, were made many years ago, when only the old One-inch Ordnance Map was available. Now more precision can be given from the six-inch Map.

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[1] *Quart. Journ. Geol. Soc.*, 1854, vol. x, pp. 222–224.
[2] 'The Geology of Parts of Oxfordshire and Berkshire,' 1861.
[3] *Journ. R. Agric. Soc.*, vol. xxv, p. 306.
[4] Memoirs, vol. iv, and the Geology of London, etc., vol. i.
[5] *Roy. Comm. Metrop. Water Supply. Appendices*, pp. 430–433.

A good explanation of swallow-holes was given in 1885, by J. HOPKINSON, with special reference to Hertfordshire.[1]

The swallows of the main mass of the Tertiary beds are taken first, from west to east, and then those of the outliers.

ALONG THE MAIN MASS OF THE TERTIARY BEDS.

Bucks. and Western Herts.

I have found but one note of a swallow-hole by the main mass of the Tertiary beds in Buckinghamshire, made by LL. TREACHER, in an account of an Excursion to Hedgerley,[2] in which he says :—"Near the road in the centre of the village is a large shallow depression having the appearance of a dried-up pond, but which," he "suggested, was one of a series of old swallow-holes in the Chalk, several more of which were observed . . . higher up the valley to the west. The floor of the valley being on Chalk, while the sides are composed of Reading Clay, it would appear that, in the course of its excavation whenever the stream cut down at any point to the porous rock its waters were at once absorbed thereby and a swallow-hole formed, the use of which lasted till the Chalk was again exposed higher up the valley, when the same process was again gone through. At the present time there is one of these holes in actual process of formation at the head of the valley near Penn Lands, into which, in rainy weather, a small stream may be seen descending."

In the side-valley eastward of Moor Park, Rickmansworth, a swallow-hole was seen west of Grove Farm, close to the county-boundary. This is a good way within the boundary of the Reading Beds, and leads one to infer that these, from here to their boundary on the north, are chiefly sand, allowing the water to sink through to the Chalk. The like occurs further north-westward along the Tertiary escarpment, as noticed by CLUTTERBUCK above, and in more detail in his paper of 1876, now to be quoted.[3]

Of the streams flowing over the escarpment of the Tertiary beds near Watford he says that they "flow in open watercourses, which here and there furrow the escarpment which overhangs the Colne. When it arrives at the junction of the clay with the sand outcropping beneath it, the water wholly or in part sinks into the earth through natural apertures usually called swallow-holes, descends into the subjacent chalk, and is added to the water in that so-called water-bearing stratum. . . . As the water which finds its way into the chalk by these swallow-holes is derived from the surface drainage of the Tertiary clays, and as their surface must not only be saturated but flooded before the water will be discharged from the surface, the supply from this source must necessarily be irregular and periodical. In some years there are no such floods ; in others, such as 1875-6, the quantity of water must in many cases be more than the swallow-holes can take in. Among the most remarkable are those found in the carrier which conveys the water from the Elstree reservoir to the river, which must be plugged when the water is discharged, to prevent the waste of a greater part if not the entire volume. At another, near

[1] *Trans. Herts. Nat. Hist. Soc.*, vol. iii, pt. 4, pp. xliv-xlvi.
[2] *Proc. Geol. Assoc.* 1911, vol. xxii, pp. 22, 23.
[3] *Trans. Watford Nat. Hist. Soc.*, vol. i, pp. 127, 128.

Letchmore Heath, in the parish of Aldenham, where a large body of water sinks in a deep depression or pit into the earth, at the junction of the sand of the Tertiary beds and the Chalk, this sand may be seen cropping out close at hand. It has been supposed that there is some connexion between this irruption (? inflow) of water and the well-known copious issue at Otterspool. There are stories of ducks having found their way thither by some subterranean passage ; and measurements of the level at which the water stands in the wells thereabout and in the direction of the pool, show an irregularity not easily accounted for but by the existence of some fault or fissure in that direction. After heavy rain the pool becomes slightly turbid, and in a dry season it has been known to cease flowing over the dam by which it is confined and over which the water usually falls. There are other swallow-holes to the north and south of Bushey Grove, in the direction of Hillfield Lodge, and Cold Harbour ; in the latter the overflowing water might be seen this year (1876) running to waste in augmentation of the floods in the rivers across the park. Again there is a remarkable instance in a meadow through which the footpath runs from Crook Log to Bushey Church, the orifice sometimes being insufficient to take in all the water flowing down the watercourse. When the water thus finds its way through the sand, or in some cases direct to the chalk, it here as elsewhere causes a rise in the water in the chalk sometimes of 20 ft. . . . half a mile from the river or outfall. By the slow discharge of these waters that of the river is augmented, though from the uncertainty due to the confined area of the chalk which can receive the rainfall south of the river, the perennial flow cannot be great. The amount to be calculated on as delivered from this source might be to a certain extent estimated by the measurement of any wells in a line between the swallow-holes and the river ; the wells near the river will not only rise with the irruption (? inflow) of the water at the swallow-holes ; but whether they be shallow or deep shafts sunk into the chalk, or deep borings, they will, if near the river, rise and fall as the river may be flooded, or in dry seasons be reduced in volume or level."

According to a later note (? by J. HOPKINSON) the principal swallow-holes of the Letchmore Heath tract are between Kendall Pound (Kendall Lodge of the newer map) and Battlersgreen.[1]

The above notice of the stream from Elstree reservoir is supplemented by J. HOPKINSON, who says : " In this stream there are now swallow-holes which usually take all the water which drains the London Clay area (partly in Middlesex) between Shenley, Elstree, Stanmore Heath, Letchmore Heath (Aldenham) and Radlett,"[2] an area which includes some short tributary-streams that join the main stream below the reservoir.

The swallow-holes westward of Radlett had been duly recorded by the Geological Survey in 1864.

Just outside the northern edge of Combe Wood, Shenley, I saw in April, 1862, some small swallow-holes in full action, after very wet weather.

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[1] *Trans. Herts. Nat. Hist. Soc.*, 1885, vol. iii., pt. 4, p. xliv.
[2] *Ibid.*, 1892, vol. vi, pt. 7, p. xxxi.

Mimms Brook.

We now come to the remarkable district of the head-waters of the Colne, formed by the joint streams of the Catherine Bourne, from Shenley and Ridge, and the Mimms Hall Brook, from Barnet and South Mimms. Though part of this tract is in Middlesex, for present purposes we may extend our county and treat of the whole.

The swallow-holes of North Mimms are probably the best known in the London Basin. They are easily to be seen, and by the place aptly named Water End it looks as if nature had set apart a piece of ground for the special illustration of such occurrences. They must have been well-known for a very long time, and may have been noticed in print in old books, as to which I have been unable to search. Enough now to chronicle the records of them by scientific men.

The first that I know of was by an officer of the Geological Survey, R. C. Trench, who said: "The brook that flows along this valley from Rabley to North Mims has no outlet, but the water is lost in swallow-holes, which thus receive the drainage of some 20 square miles of country."[1] Clearly, however, he did not see the brook in flood.

Then R. W. Mylne referred to them in his evidence before the Royal Commission on Water Supply given in 1867,[2] in which he says that there is "an isolated clay catchment basin of 23 square miles, which has no direct surface outfall, the central and lowest part of which is between North and South Mims, where the surface is chalk, and several swallow-holes exist . . . which receive and absorb the drainage water of the district . . . the entire volume of the drainage shoots down from off the clay lands on to the chalk, and pours into numerous swallow-holes."

R. E. Middleton visited the Mimms swallow-holes in 1892, and referred to them in his Report to the Royal Commission on Metropolitan Water Supply (*Appendices*, 1893, pp. 504, 505); but the following detailed account practically covers his remarks, and begins from higher up the valley.

Since these swallow-holes were first noted by the Geological Survey I have had the advantage of seeing them several times, down to 1915, and of fixing sites on the six-inch Ordnance Map. In 1898 I was therefore able to give an account of the whole,[3] which account can now be used, with the addition of various details, in a systematic arrangement from the top of the valley downward.

It is to be noted that some of the swallow-holes in the southern part of the parish of North Mimms, and the bordering part of South Mimms, differ from those along the junction of the Tertiary beds and the Chalk (which have been described above), and are more allied to those of the Mole, in Surrey,[4] the stream, which is a bourne, or intermittent stream, being lost because the saturation-level in the Chalk is below the bottom of the valley, except after wet seasons. The swallow-holes near the junction of the Tertiary beds and the Chalk act in all seasons, except when it is so dry that there is no surface-water flowing down the slopes.

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[1] The 'Geology of Parts of Middlesex,' etc., 1864, p. 20.
[2] Minutes of Evidence, 1869, p. 281.
[3] *Trans. Herts. Nat. Hist. Soc.*, vol. x, pp. 66—68.
[4] *See* 'Water Supply of Surrey,' 1912, pp. 62—67.

The highest swallow-holes that I know of here are on the Catherine Bourne, close to the county-boundary, and in June, 1893, these were dry. The one practically touching the boundary is lower than the stream.

In the Mimms Hall Brook there may be small swallow-holes about 400 yards south-west of Mimms Hall, some 70 or 80 yards lower down; about 220 yards a little north of west from the Hall; at the slight bend over 300 yards north-north-west from it, and about 50 yards lower down; but these are merely small hollows in or at the side of the channel. Nothing notable is met with until we get to the sharp bend in the stream, a third of a mile northward of the Hall, where a little cliff has been cut on the right bank of the stream, and a marked set of swallow-holes can be seen. Here, on May 2, 1893, water was sinking in slowly at various spots, but on June 9 the place was dry. On some later occasions a great deal of water has been seen flowing into the Chalk at the various successive holes.

Below this there is a succession of hollows in the bed of the stream, some of which hold water whilst the parts between are dry, and at the next sharp bend, some 150 yards below the big set, there is a fairly marked swallow.

It may be of interest to give here an analysis of the water going down this swallow-hole on 11th April, 1908, made by W. T. Burgess, in parts per 100,000.[1]

Total solid residue	36·64
Ammonia, free	·072
Ammonia, albuminoid	·032
Oxygen absorbed in 4 hours, at 80° Fahr.	·560
Nitrogen as nitrates	·125
Nitrogen as nitrites	traces.
Combined chlorine	2·1
Total hardness (by soap-test)	21·5

As would be expected "The water was turbid and brown. It was very impure compared with the supply obtainable from deep chalk wells."

In the meadow, some 450 yards north-west of Hawkshead Farm, and some 40 yards eastward of the stream, there is a swallow-hole which can act only when the stream overflows. At the Excursion of the Geologists' Association, in March, 1916, this was seen to have been in action a very short time before, and one hole in the crater-like hollow was distinctly open.

The first full description of the swallows of Water End was given by J. Hopkinson,[2] and it is notable how continued reference to the matter seems to enlarge the area of supply. He says: "The swallow-holes here (which must include others above, not then known to Hopkinson) absorb most of the drainage of about 40 square miles, the stream from the south draining about 30 square miles, and that from the north about five. The whole of the London Clay area between Bell Bar (south-south-east of Hatfield), Northaw, Potter's Bar, Chipping Barnet, Barnet Gate, Green Street, Shenley, Ridge Hill, and North Mimms is drained by the southern (main) stream; while the northern (tributary) stream drains the area between North Mimms,

[1] *Proc. Geol. Assoc.*, vol. xx, pt. 7, p. 502.
[2] *Trans. Herts. Nat. Hist. Soc.*, 1892, vol. vi, pt. 7, pp. xxix-xxxii.

Dulsham Green (Dellsome of the newer map), Bell Bar, and Brockman Park." It will be seen, therefore, that the main stream largely comes from Middlesex.

"At this spot (Water End) there are channels which the water has gradually made for itself down which a man might be carried. I have seen these swallow-holes when no water reached them; I have seen them when a powerful stream came from the south and rushed down them in torrents with a roar which I heard long before I could see what was its cause; and I have seen them, or rather the spot where we know they are, when they were covered by a sheet of water forming a peaceful lake into which streams flowed from north and south, and out of which a stream flowed on through Mimms Park and into the permanent river of the Colne. Then doubtless the plane of saturation in the Chalk was raised to above the apertures of the swallow-holes, in fact to the level of the water in the lake."

In 1902 we had HOPKINSON's latest note on these swallow-holes.[1] Speaking of the Colne, he says: "It disappears in a 'swallow-hole' in the Chalk. If this cannot take it all, there is another ready a little farther on, and so on as far as the swallow-holes at Potterells (Water End), near North Mimms. Seldom does any water get beyond these great chasms, down one of which at least a man might be carried; but sometimes they cannot take it all, not because they have not sufficient capacity, but because they are full owing to the plane of saturation having risen in the Chalk up to their capacious mouths. Then there is a flood, the river forms a lake hiding the swallow-holes from view, and the bed of the Colne, dry for some distance below this point year after year, is unable to carry off the water, its banks overflowing, submerging the meadows, and rendering some of the roads between Colney Heath and Smallford impassable. The water which sinks into these swallow-holes is probably conveyed in channels in the Chalk into the lower part of the valley of the Lea, for that would be its direction if it follows the dip of the Chalk," with which conclusion I hardly agree: it seems to be the fourth view as to the ultimate disposal of the water.

J. M. WOOD writes to me (June, 1920) that he has had these swallow-holes under personal observation for the past thirty years, under all conditions, from dryness to flooding of the land, and that he agrees with the above description. Furthermore he has very heavily dosed them with fluorescene; when a moderate flow was taking place, and had observations made at springs and wells in the Valley of the Lea for days after the dosing, but failed to detect any trace of colour in these. Hence he concludes that the swallow-holes discharge into the Valley of the Colne, and not into that of the Lea.

Turning now to side-valleys, all on the right or eastern bank, in that from Potter's Bar I found, in May, 1896, three little hollows, which may be sink-holes, just north of the narrow marsh, about 265 yards north-east of Warrengate Farm, whilst just southward, along the hedge across the marsh to the stream are three small sink-holes, which were dry, and presumably act only when the marsh is flooded.

In the next valley to the north there are swallow-holes in Deep Bottom or Gobions Wood, north-westward of Littleheath, notable

[1] Victoria History of Hertfordshire, p. 30.

enough to have got marked on the six-inch Map (Herts., Sheet 40). They were all dry in June, 1893; but in August, 1915, the highest one, where a track crosses the water-course north of Bolton's Farm, was well in action, water flowing in from the east into a large hole, at the bottom of which chalk was seen, though most parts were well covered with mud, brought down by the stream. Two others are marked on the map, lower down in Deep Bottom, the lowest being in a large hollow; but these are hidden by the wood.

We were told, by the gamekeeper, who accompanied our Geologists' Association party in 1915, that after heavy rain the whole of this valley-bottom was under water.

It is to be noted that these swallow-holes show an error in the old Geological Survey Map (Sheet 7), presumably from a small local uprise of the beds having escaped the notice of R. C. Trench, who had to work on the old and not too exact one-inch map. This uprise may be connected with that which has given rise to the Chalk-inlier at Northaw, to the east-south-east, and it may have some effect in hindering the passage of water underground in the Chalk from the swallow-holes of the Mimms Hall Brook north-eastward.

Lastly we come to the small tributary from Welham Green, south of Hatfield, which passes through the northern part of Potterells Park, receiving the sewage of the house some little way above the highest swallow-hole marked on the Ordnance Map (Herts., Sheet 35).

This highest swallow is about 225 yards north-west of the house. A little farther down, westward of the house, there was water for a short way in June, 1893, and the second swallow-hole on the map, about 330 yards south-west from the first, was in action. There are others just below, as the stream debouches on to the great tract of swallow-holes at Water End.

It is to be noted that J. Hopkinson has described these last under the heading Potterells, which it is more convenient to keep for the side-valley: the others are not in Potterells Park.

Eastern Herts.

R. E. Middleton has given us the following note: "A small stream running from near Traveller's Farm, about a mile and a quarter south of Hatfield . . . collects surface water from a small area, said to be one square mile, and loses itself in a curious hollow called Hoe (How) Dell, near the Old Rectory." It is in the rectory-grounds, south-eastward of the house. "The dell is of considerable depth, 20 ft. or more, I should say, and the end towards Hatfield is closed by a bank, which may be artificial, but appears to be natural. The length of the dell is about (less than) a quarter of a mile, in the bottom are several swallow-holes, into which the water, as a rule, disappears; but on two occasions, some seven and 17 years ago (? 1885 and 1875), the quantity of water discharged into the dell has been so great that it has surmounted the bank and flowed into Hatfield, causing disastrous floods. In order to prevent flooding in the future, two or more of the swallow-holes have been timbered to a diameter of some 4 ft. and to a depth of perhaps 20 ft., and gratings have been put over them."

"Mr. (U. A.) Smith says there are other swallow-holes nearer Hatfield."[1] It may be to these that MIDDLETON alludes (in p. 609 of the volume) when he says, "There are swallow-holes in Hatfield Park, alongside the Hertford Road, and in the course taken by water when it overflows from Hoe Dell."

Presumably the swallow-holes noted by COLEMAN (*see* above, p. 82) are the same as these.

This is the most easterly part along the Tertiary escarpment at which swallow-holes have been recorded, though one would expect that they might occur in other places between Hatfield and Hertford.

Some have been found, however, further eastward, in the Tertiary tract, than any above described, in the inlier of Reading Beds and Chalk near Northaw, and in the inlier of Reading Beds further northward; but no account of them has been published.

In 1893, when examining the district with T. H. MARTIN, then Engineer to the Barnet Water Company, we visited the Northaw inlier, and the following notes are taken from a Report which I made in June of that year: "No swallow-holes have been recorded as occurring here; but we found good evidence of them, though they are far less marked in form than is the case in many other places. The stream has been artificialised, and it seems to have been diverted from a course which would lead it slightly nearer to the large old chalk-pits. When full it overflows into slight hollows, sometimes into the pits, and then the water sinks into the Chalk. The drainage too from the fields to the north is now led into one of these pits."

When carrying on the new Geological Survey lately R. W. POCOCK found a set of swallows in the other inlier, along the Cuffley Brook, by the northern border of Great Wood, also in the parish of Northaw, and he is kind enough to show these to me, enabling me to take the following notes:—

In summer this branch of the brook is dry; but in January, 1916, there was a good flow of water, both in the main stream and in its various tributaries. Where one of these tributaries comes in, from Hell Wood, about half a mile west of Newpark Farm, in a projecting piece of the wood, south-west of the farm, there are some fairly deep hollows, with the bottoms below the level of the brook, and these seem to be overflow swallow-holes, that is, depending for their action on the overflow of the stream over the low lip between them and the stream. They are therefore of the same type as those at Fredville, on the Mole[2], but on a smaller scale. There seemed also to be places in the stream about here where water went in.

Just below these another stream comes in from the north, and this seemed to end on its eastern side in a pool, at the edge of the wood.

The next little stream, from just west of Newpark Farm, flowed into a slight hollow on its western side, before reaching the wood, and was a clear case of a swallow or water-sink.

There are also swallow-holes, of a fairly marked kind, in the wood, on the other or southern side of the stream, fed by northerly flowing streamlets of the clay-slope. Some of them were seen during an ex-

[1] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 597.
[2] *See* 'Water Supply of Surrey,' 1912, pp. 65, 66.

cursion of the Geologists' Association in May, 1916; but only one had any water in it. At that time, too, those above described were also out of action.

G. Barrow tells me that the finest swallow-hole here is some way lower down the stream, by its side, and just west of the railway (in progress), about 500 yards west-south-west from Barleigh.

All these swallow-holes, which are in a most out of the way tract, are another case of water flowing down a slope of London Clay and sinking into the sand of the Reading Beds. The sinking in of water may go on more or less along the whole of the sand-outcrop.

J. M. Wood tells me that there are swallow-holes in Balls Park Estate, between Hertford and Haileybury.

ON TERTIARY OUTLIERS.

Lane End Outlier.

There are two swallow-holes on the northern side of the high road between Bolter End and Lane End.

Around Park Hill (the eastern part of the outlier, not named on the newer Ordnance Map) the boundary of the Tertiary beds is marked by many.

At the southern limb of the outlier, west-south-west of the ruined church at Ackhamstead (another name that does not appear on the newer map), the water that flows over the moist ground of Moor End Common, on the north, collects, inside the wood, into streams, which, having a sharp fall, have cut for themselves channels of some depth, often rather steep-sided and with miniature waterfalls; and they all flow into a large deep swallow-hole at the eastern end of the wood, in the Chalk, the Reading Beds coming on at once above. Presumably it is to this that H. J. O. White refers in saying "the swallow-hole at the eastern corner of Moor End Common (in Moor Copse) is an exceptionally good example . . . with vertical sides which show the junction of the Chalk and Reading Beds, and a sandy floor, in which open fissures are sometimes to be seen."[1]

Beaconsfield Outlier.

In the small wood just north of Helmet (Hillmott's Farm of the newer map), south-east of Beaconsfield, there is a long deep hollow, from the track through the wood down to the southern edge. It ends abruptly either way, and I could not make out whether it was artificial or a swallow-hole. At its southern end, almost vertical, it showed what may be a junction of the Reading Beds and the Chalk.

Coleshill Outlier, southward of Amersham.

There is a swallow-hole east of Brickwich, another at the farm west of Quarrendon; and from Brentford Wood to Coleshill Green (Coles Hill of the newer map) there are many swallows, one indeed in most of the re-entering angles of the boundary-line of the Reading Beds.

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[1] *Mem. Geol. Survey.* The Geology of the Country around Henley-on-Thames, 1908, p. 66.

Hodgemoor Wood Outlier, westward of Chalfont St. Giles.

This was formerly called after Frog Hall, a name not on the newer map.

There are swallow-holes at the following places :—Nearly a third of a mile eastward of Stocking's Farm. About the same distance further eastward. Near Rowlings Farm. Nearly half a mile north-westward, by the road.

Cowcroft Outlier, east of Chesham.

A swallow-hole was seen at the edge of the wood just south-west of Cowcroft.

Pollards Wood Outlier, northward of Chalfont St. Giles.

There is a swallow-hole at the edge of the wood east of Ivy House (Inn of the newer map, by Harewood Down Farm).

Newlands Outlier, east of the Chalfonts.

There is a swallow-hole on the eastern side, just south of Bowers, a name not on the newer map, which differs greatly here : the site must be about a quarter of a mile eastward of Roberts's Farm.

O'Connorville Outlier.

Formerly called after Chorleywood. Just south-west of Kings Farm is a swallow-hole : presumably it is this which is marked as Swillet on the newer Ordnance Map (and on Herts. 43). J. Hopkinson has noted that another, west of the former brickyard (? Chorley Wood Kiln of the older map), now a garden, has been plugged, in order to form a pond.[1]

Abbot's Langley Outlier.

There is a small ill-marked swallow-hole on the southern side of the road about a third of a mile south-south-west of the church.

Ayot Outlier.

The swallow-holes of this outlier seem to have escaped notice until lately, except for a mention by the Rev. W. H. Coleman (*see* p. 82) and a doubtful reference by W. Topley to a hole in the hollow southward of the Rectory (Digswell),[2] a spot which I am unable to identify ; but visits to parts of this outlier in 1919 and 1920 have shown the presence of well-marked swallow-holes.

The least conspicuous of these, seen in December, 1919, is on the south-western side of the Hertford branch railway in the little valley at the parish-boundary, southward of the small wood named Gutteridge Grove (Herts. 28, S.E.). This is in a Drift-tract, and the water of a tiny occasional stream seems to sink into the gravel, which overlies the Chalk : strictly, therefore, this does not belong to the Tertiary outlier.

A much more marked example was seen, in the same month, in the hollow south-eastward of Ayot Green : small springs started about 350 yards from the edge of the Green, and the resultant stream flowed southward, through a small wood, at the further end of which, after a course of little over 100 yards, it disappeared in a large hollow, without outlet.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1890, vol. v, pt. 8, p. xxvi.

[2] 'The Geology of the London Basin,' 1872, p. 237.

On January 6th, 1920, during a frost, I saw another equally well-marked swallow-hole, only about 230 yards eastward of the springs above-noted, by the western side of the railway, east-south-east of Ayot Lodge, Ayot Green. A small stream (presumably the result of gravel-springs and clay-drainage) trickled down along the foot of the embankment into a large, deep basin. There was then only a little water in this basin; but a workman on the railway, who had always lived near by, told me that after heavy rain the basin got full, the water then being above the top of the fence of the railway, until it flowed over the top of the basin, on the south. This I have no reason to doubt, for at the time there was good evidence that, only two or three days before, the level of the water must have been some 4 ft. higher. There had been a frost, the surface of the pond was covered with ice, the water began to sink into the earth (a process which the workman said usually went on at the rate of about a foot a day), and at last the ice, left without support, gave way, and the slope of the basin was coated with it. I should say that the depth of the water in the basin, when it is full, must be about 15 ft.

Neither of these occurrences are in any way marked on the six-inch Ordnance Map (Herts. 28, S.E.).

MISCELLANEOUS.

Valley of the Ver.

According to J. Hopkinson, at Harpendenbury, just above the village of Redbourn, in normal conditions of rainfall the river "decreases in volume . . . and in an orchard a little below the farm it finally disappears down a swallow-hole, the river-channel continuing dry for three-quarters of a mile."[1]

Valley of the Mimram.

According to R. E. Middleton there was once a swallow-hole below Frogmore, on the east of King's Walden Park, "which was stopped up 12 years ago (? 1880), and the flood water from the park, instead of passing into the swallow-hole, runs down the road."[2]

Valley of the Beane.

From the same source we have it that in the head part of the valley of the Beane "there are swallow-holes . . . and much of the surface water must percolate" (p. 562). Farther on (p. 629) he says of the Ardeley tributary, "This branch only runs down to the moat at Ardeleybury in very wet weather, as there are at least two large swallow-holes in its course, one near St. John's Wood, and one, in the same field, opposite Walkernbury. The upper . . . is about 40 ft. in diameter, and there is (February, 1893) a good deal of water in the bottom of it; there is a small stream running into it, but the water sinks nevertheless. A bank has been put across below the swallow hole to make it take more water."

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[1] *Trans. Herts. Nat. Hist. Soc.*, 1911, vol. xiii, pt. 3, p. 219.
[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 560.

The second swallow-hole, lower down, contained some water but had no stream running into it. It is rather smaller. Chalk was shown in it, almost to the surface, and it, too, had been banked to prevent water passing it.

W. Hill has given the following description of a swallow-hole in the valley southward of Almshoe Bury, in the parish of Ippollitts, in an account of an excursion. It is "at the upper end of a long narrow meadow. There is a depression of about 10 yds. across, and about the centre of it is a basin 8 ft. by 4 ft. and $2\frac{1}{2}$ ft. deep. Into this the water draining from the valley runs and disappears. Unfortunately, in consequence of a five weeks' drought, the quantity was a mere trickle (27 April, 1912), but in wet weather the amount is considerable. . . . The meadow itself, about 350 yds. in length by 80 in breadth, is a depression some 10 ft. below the surrounding levels. . . . Whether the water finds its way into the Chalk or into drift filling the valley is a matter for investigation."[1]

[1] *Proc. Geol. Assoc.*, 1912, vol. xxiii, p. 220.

CONTAMINATION AND RISK THEREOF.

It should be understood that in the following remarks we are dealing with the history of the past and not finding fault with the present conditions. All history has an interest, and it is from the experience of what has happened that we are enabled to prevent present evil and to safeguard the future. This is certainly the case in sanitary matters, and, moreover, there is something pleasing in the record of old conditions, which show the improvements that have been made in late times.

The few notes now given are arranged in the order of date. Most of them are got from the Reports of the Local Government Board. Many other cases of risk of pollution of water-supply in villages must be known to Medical Officers of Health, whose Reports can be referred to.

Ware.

In 1867 evidence was given that abundant water was got from private wells in gravel, and that cesspools were made in the same, with resultant contamination in cases.[1]

Chilton.

In 1873 an outbreak of enteric fever in Marylebone was traced to a milk-supply from Chilton Grove Farm, north-west of the village, and the pollution was found to come from the farm-well of which it is said: "The position of the well was such . . . that, notwithstanding the surrounding soil was a stiff clay (Kimmeridge Clay) this had been so much broken up . . . as to render soakage either from the privy, the drains, or the pigsty not improbable. The water from the well had for some time been disused in the farm for drinking and cooking purposes, on account of a gradually increasing distastefulness, and for these purposes water was obtained from a spring on the hillside east of the farmhouse, at about a sixth of a mile or more distant."[2]

The water from the farm-well was used for the dairy, and hence the contamination of the milk which went to Marylebone. For analysis of the waters *see* p. 286.

Baldock.

The following remarks are from a Report to the Local Government Board by Sir T. Thorne, in 1874:—

"In September, 1873, enteric fever broke out in the town, and W. Jenner, the Medical Officer of Health, came to the conclusion that it "was associated with the use of polluted water."

The water-supply was "derived from wells . . . sunk in the chalk rock to a depth varying from about 10 ft. to 50 ft. Many of these wells have unquestionably been polluted by soakage (*a*) from cesspools, which, until quite recently, were general . . . (*b*) from piggeries without any means of artificial drainage, (*c*) from heaps of refuse, and (*d*) from imperfect drains; and it is evident, both from an inspection of a considerable number of the wells and their surroundings,

[1] Second Report of the Commissioners. . . . Pollution of Rivers, vol. ii, pp. 169, 174, 175.

[2] Rep. M. O. Privy Council and Loc. Gov. Bd., n. ser., No. ii, p. 123.

and also from consideration of the length of time during which this pollution of the water-bearing strata has been going on, that constant risk to health must remain if this water supply is retained. . . The only wells which appear at all likely to remain free from the risk of pollution are such of the deeper ones as are so constructed as to exclude soakage from the surface soil. In connection with the prevalence of enteric fever it is worthy of note that the greater portion of the outbreak was associated, in point of time, with the construction of the new sewers, and that this work necessarily caused considerable disturbance of the polluted strata through which the water, by which the wells are supplied, flows."

Hitchin.

In 1883 [Sir] W. H. Power reported to the Local Government Board on an epidemic of enteric fever.[1] He described the waterworks (the source being the Bath Spring at Charlton), and said that "from the story that has been told respecting the method of conveyance of the water to the town there is obvious suggestion of many chances of pollution encountered by it on its way thither, and it cannot therefore be regarded as uniformly a safe supply" Formerly risks of pollution were more abundant, but improvements were made; but others remained, notably from the water being taken along a clay-socketed earthenware pipe, allowing infiltration from various sources, and it was found in 1883 that an overflow-pipe at the pumping station (for passing surplus water into the Hiz) "permitted on occasion reflux of the river water into the tank." This explained the occasional turbidity which had been noticed in the water. This was at once rectified. As "the Hiz, which in its course through the town is hardly more than a ditch a few feet in width, receives refuse matter cast into it" it is clear that this was a great source of danger. Such communication probably occurred after the heavy rainfall of December 30 (1882), which caused a sudden and rapid rise of the water in the river, at a time when the water had been pumped down in the pumping well.

It seems therefore "that in all probability there has been direct relation between the circumstances of the pollution, on the 30th December, of the public water service, and the outburst of fever in mid January," and probably an earlier outbreak, in mid-December, had a like cause. It is notable that remedial measures, in each case, were followed in about two weeks by cessation of the fever.

Of course, since then the water-supply has been made safe.

Barnet.

I will repeat some remarks made in an address in 1886[2] relating to two places in Hertfordshire:—"Twenty-one years ago an 'Absorbing Well' was made for the sewage of New Barnet. It was foreseen that it would hardly do to carry this into the Chalk, the great water-bearing bed of the district, and it was ended in sandy Tertiary beds, between the London Clay and the Chalk (*see* p. 186). As, however, water is sometimes got from those beds, this proceeding is not without danger. Moreover, there is also the danger of there being some communication

[1] Report (not numbered), pp. 2, 4–6.
[2] *Trans. San. Inst.*, vol. viii.

between the Tertiary beds and the underlying Chalk, from which the water-supply of the place is got." This sewage-well has been abandoned however.

Tring.

"I will now allude to a case referring to surface water-supply, for information on which I am indebted to my colleague Mr. Jukes-Browne. Part of the drainage of this town is carried away by a sewer which empties itself into the canal-reservoir to the north. Before this sewer was made the reservoir received only spring-water, a matter of some importance, as some neighbouring villages drew their water from the stream that flows from the reservoir. After the turning in of the sewage, in summer, when the water in the reservoir was low, it stank abominably; and worse, diphtheria, typhoid fever, and other such diseases, were frequent in the villages." Measures were taken to get rid of this evil.

Buckingham.

Writing in 1888, Dr. H. F. Parsons says[1]:—"The water supply of Buckingham is mostly derived from pumps and wells, public and private, but Church End is supplied by a copious and unfailing spring, the Bath Lane spout. . . . The wells in the town are of moderate depth, about 30-40 ft., and are said to yield a good supply. . . . Water, however, obtained from wells so situated must be looked upon as suspicious, for as the town is nearly cut off by the river valley from any large extra-urban gathering ground, the water which the wells yield must be largely derived from the rain which has fallen in the area of the town, and which in its way would carry with it impurities from the surface, and from leaky drains, cesspools, &c. It is rarely the case that the upper part of a well is made watertight with a view to exclude soakings from the surface soil." He had evidence that such communication took place, and that the water of the Bath Lane spout was polluted in like manner, and he concludes that the water-supply was the chief cause of the spread of enteric fever at first.

He remarked "that typhoid fever may be produced by drinking water containing the specific poison of that disease, even though the total amount of pollution present may be so small as to be undiscoverable by chemical analysis." For said analysis, *see* p. 270.

Wycombe Marsh.

In 1896 Dr. G. S. Buchanan reported on an outbreak of fever in this village.[2]

"The cesspools of the village, whether for slop water or for excreta, are commonly placed in the gardens. Although they are seldom emptied, they do not often overflow, probably because their structure allows of rapid percolation of their liquid contents into the soil. The water supply of each house or group of houses is obtained from a well or wells, usually a dip-well, in the garden, and in proximity to the cesspool. . . . The steining of the shallow wells . . . permits water to pass readily through it. Throughout the village the level of the ground water is high."

[1] Report to Local Government Board, No. 25. pp. 2–5.
[2] *Ibid.*, No. 102, pp. 2. 4–8.

"In the narrow alluvial plain . . . the ground is saturated with water to within a very short distance of the surface, as witnessed by the springs . . . and the level of the water in the surface wells. As in other valleys there is a general downward movement of soil water in the trough of the valley in a direction more or less parallel to the river, and here the porous character of the soil allows this movement to be comparatively rapid."

The sewage-farm for High Wycombe is "some 500 yards above the village of Wycombe Marsh, and it seems certain that the drainage of the farm in part contributes to the ground water which supplies the shallow wells of the village," and the conditions of sewage-treatment at the farm did not "offer any surety that pathogenic organisms . . . would be destroyed in their passage through the farm." As there had been fever at High Wycombe, to a considerable extent, before the outbreak in the village, it is not surprising that the inquiry led to the conclusion that pollution of soil-water by the sewage-farm was the cause of the evil, and that the wells of the village are liable "to yield water dangerous to the health of persons consuming it."

Eton Rural District.

Writing of this in 1899 Dr. R. W. Johnstone says :—[1] "Water is obtained in large measure from shallow wells. . . . Cesspools, buried excrement, leaky privy pits, and manure heaps, are sometimes found in dangerous proximity to wells of this sort. Owing to the loose texture of the gravel in which many of these wells are dug, there is special liability to contamination from organic matter impregnating the surrounding soil." The Medical Officer having "year by year analysed samples of water from certain of these wells . . . many have been found to show chemical evidence of pollution, and have been closed."

Edlesborough.

According to Dr. R. D. Sweeting,[2] in 1904 an outbreak of enteric fever in this village, and in the contiguous Bedfordshire one, of Eaton Bray, was traced to some influence at the national school of Edlesborough. He says :—"The water supply at the school is from a pump in the school yard. No one could tell me the precise position of the well connected with it ; I therefore had the ground opened with a view of finding this out. Eventually the well was discovered within two feet of the site of a considerable heap of decomposing excrement . . . which had been accumulating there for some weeks prior to the outbreak of enteric fever, but which had been removed after this had begun. The well is shallow, the water in it standing at 7 ft. from the surface of the ground with a depth of about 8 ft. Its sides are dry steined with loosely packed bricks. The crown or arch of the well is not concreted or cemented. Being sunk in the chalk to so slight a depth there is abundant opportunity for the entrance into the well of surface soakage. Some of the bricks at the side of the well, near the surface of the water, show signs of black discoloration, as if from sewage. Indeed, the physical circumstances of this well are such as to expose the water furnished by it to very grave suspicion."

[1] Report to Local Government Board, No. 141, pp. 2, 3.
[2] *Ibid.*, No. 203, pp. 3, 6, 7.

"The observed facts of this outbreak . . . are more consistent with a hypothesis of a well-water becoming suddenly infective, than with any other. Indeed the almost exclusive incidence of the fever upon the children attending Edlesborough school would seem to point definitely to the school well as the cause." But how the specific contagion reached the well was not found out.

The well was disused and ordered to be closed.

"The lesson . . . is the potential danger to which the shallow wells of these two villages is subject. There can be little doubt but that if the specific contagion of enteric fever becomes introduced into other wells . . . as it has by some means or other been conveyed into the Edlesborough school well, the results may be equally disastrous. A public water supply is urgently required for both of these villages."

PUMPING INTERFERENCE.

In Hertfordshire we have several interesting cases of the effect of pumping at various wells on the water in other wells or on neighbouring springs: in some cases indeed special experiments were made to test such effect.

Bushey.

The Rev. J. C. Clutterbuck[1] has referred to the effect of pumping, at the Experimental Well in Bushey Meadows, on other wells, at Leavesden (some two miles off), and at Trolly Bottom (some three miles); but the effect was so small, 5 ins. only in the first case, that there is great doubt as to the cause; and when the observations are carried so far as Gaddesden Row (about ten miles off) we cannot accept the idea.

Of this experimental well R. E. Middleton says:—"A series of pumping experiments were made to test whether surrounding wells were affected thereby, and 1,800,000 gallons were pumped per day for three days and nights. Mr. Clutterbuck, at whose instance the experiments were made, maintained that the surrounding wells were affected to considerable distances, while the engineer in charge stoutly asserted that, from his personal observations, they were not affected in the least."[2]

It is to be noted that we have here two somewhat vague words, "surrounding" and "considerable." Wells a long way off would hardly be affected; but one can scarcely doubt that wells near by would be. Hnwever, the pumping was for a short time only.

Dudswell.

U. A. Smith has drawn attention to the decrease in the springs feeding the watercress-beds at Dudswell, in the parish of Northchurch,[3] and to steps taken to remedy this. "In the early part of 1890 a bore pipe . . . was driven down in the bed of the river, adjacent to the watercress beds . . . and at first the water rose 6 ins. above the top of the pipe, but this quantity gradually decreased, and in May, 1891, the water stood fully 12 ins. below the top of the tube, and in September, 1891, the water had further sunk to 4 ft. below the top of the tube. During the time the vertical sinking of the 3 ft. of water occurred, the Grand Junction Canal Company were pumping from a well . . . near the 'Cow Roast' (a little higher up the valley), and during the same period also the source of the river came a mile lower down the bed than it had been before the pumping commenced."

"Several other bore pipes were subsequently put down, but the supply has not been materially increased thereby."

Of the nine borings, the highest (the first alluded to), being 162 ft. deep, and the top of the tube 371·39 ft. above Ordnance Datum, whilst the rest are mostly 90 ft. deep, but run up to 105 and decrease down to 353·81 ft. above Ordnance Datum.

Other notes on this subject are to be found on pp. 576, 577 of the same volume.

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[1] In his Letter to Sir J. Sebright, 1841, p. 11.

[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 599.

[3] *Ibid.* p. 402.

Cow Roast.

The well-known experiment made at this site has often been described. The first notice of it that I have is by S. Clegg, one of the engineers in charge,[1] who says :—"In the early part of 1849, the Grand Junction Canal Company caused a well to be sunk to a depth of 75 ft., with bore-holes below that depth (*see* p. 236) . . . to raise water from the chalk, for the supply of the summit level of the canal."

"This well was 6½ chains north of the highest source of the Bulbourne."

"The observations commenced on the 23rd of May, 1849, and it was soon perceived that the level of the water in a well situated five chains to the west, and in a pond three chains to the east, was always lowered, to an extent corresponding with the quantity of water drawn from the Canal Company's well."

"Almost immediately on the cessation of pumping, the waters invariably rose, until the former level was reached."

This led Messrs. Dickinson & Co. to make "more extensive and accurate experiments. Accordingly three gauges were placed across the Bulbourne ; the highest being 528 yards, the second 660 yards, and the third 957 yards from the pumps."

The pumps were then worked "for ten days, from the 27th of June, without cessation ; after ten hours pumping, the water ceased to flow over the highest gauge, on the ninth day, the second gauge was dry, and on the tenth day the depth over the third gauge was reduced from $7\frac{3}{8}$ ins. to $5\frac{13}{16}$," and the water "in the well at Norcott Court (about three-quarters of a mile off) was reduced 1 ft. 3 ins. . . ."

"On the 7th of July the pumps were stopped, and remained at rest for ten days, and during each day the waters were observed to rise. On the second day the water reappeared in the pond, on the third day it ran over the middle gauge, and on the tenth day it had risen at the lower gauge to within $\frac{3}{16}$th of an inch of its original depth, whilst in the well at Norcott Court it had arrived within 9 ins. of its original level."

"It was argued . . . that the water sources of the Bulbourne were from the upper portion of the chalk, and that if the brick steining of the wall was rendered water-tight, by being surrounded with puddle, the higher chalk water would be prevented from draining into it, and therefore that the pumping would not affect the stream. This alteration was made . . . but after the operation, the results of the pumping were quite as conclusive as before. Indeed the effect extended over such an area, that the water at a gauge across the Bulbourne, three miles below the pumps, was lowered more than half an inch."

In noticing these experiments, Sir J. Evans explains that "a firm of millers (Messrs. Dickinson) applied . . . for an injunction to restrain their pumping, on the ground that water so pumped would otherwise flow into the river," and he gives the distance of the gauges down the stream as 504, 600, and 946 yards, "over which the water flowed $\frac{5}{16}$in., $2\frac{1}{8}$ ins., and $7\frac{3}{8}$ ins. respectively."[2]

In the volume just quoted from, Clegg's description is reproduced (p. 576), and R. E. Middleton gives some extracts from Cubitt's

[1] In discussion on paper by P. W. Barlow, *Proc. Inst. C. E.*, 1855, vol. xiv, pp. 69, 70.

[2] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 443.

Report of 1849 (p. 548), from which the following further details are taken.

In the first experiment of continuous pumping from June 27 to July 7, 1849, 1,231,000 gallons a day were pumped and the level of the water in the well was lowered about 60 ft., to 533 ft. above Ordnance Datum.

	June 25, Canal empty.	June 26, Canal filled.
1st gauge discharged	$\frac{3}{4}$ gallon a minute.	5 gallons a minute.
2nd ,, ,,	16 gallons ,,	33 ,, ,,
3rd ,, ,,	266 ,, ,,	322 ,, ,,

"After one day's pumping the upper gauge was dry, the discharge from the second gauge was 25 gallons, and from the third 322 gallons a minute; thus while 1,231,000 gallons had been pumped from the well, the upper gauge had lost 7,200 gallons, the second gauge 11,520 gallons, and the third gauge had lost nothing."

"On the 6th of July . . . after 244½ hours continuous pumping, the second gauge ran dry, while the third one was discharging 237 gallons per minute, thus, while 11,160,000 gallons had been pumped from the well, the second gauge had lost 218,000 gallons, and the third gauge 562,000 gallons in all."

"On July 7 . . . this experiment terminated . . . and the third gauge was discharging 190 gallons per minute."

Further experiments were made later.

A table of the fluctuations of the water-level from 1851 to 1892 (monthly) is given on p. 667 of the same volume, to which the reader is referred for details. They are given in feet of water, the lowest record being 3 ft. in October, 1890, and the highest 20 ft. in March, 1882.

"In the summer of 1891 the Canal Company were again short of water for their summit level, and they again opened the well . . . and pumped water from the chalk. . . . On the pumping being started in July, 1891, the effect upon the river was very soon noticeable, the dry portion extended rapidly downwards, and the water in the deep bore holes was also affected. The water in the bore hole nearest to the pumping, about three-quarters of a mile distant, which previously to the pumping was a few inches only below the top or [of] the iron pipe, gradually sunk until it was four feet below the top."[1]

Of the Cow Roast well R. E. MIDDLETON writes :—"Since the year 1889, or thereabouts, the level of the water in this well has been affected by pumping from the wells of the Chiltern Hill Water Company, which are situated a short distance above the Cow Roast well, and in the same watershed."[2]

The effect of the pumping at the Canal Co.'s well was again alluded to by U. A. SMITH,[3] who, after noting the old experiments, says :—"Pumping from this well has taken place in late years in dry seasons with a marked effect upon the district. A number of comparatively shallow wells in the village of Aldbury, two miles up the valley, being affected. They gradually lost their water until it became necessary to seek a supply from the Chiltern Hills Water Company. . . . The first marked lowering of the wells occurred in the dry summer of 1891."

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[1] U. A. SMITH. *R. Comm. Metrop. Water Supply. Appendices*, p. 394.
[2] *Soc. Eng.*, 1896, pp. 164, 166.
[3] Underground Water Preservation Association . . ., 1902 ? pp. 31, 32.

"The Town Farm Well at Aldbury, two miles from the Company's well, clearly indicated when the pumping was going on."

New River Co.'s Wells.

J. FRANCIS has said of the New River Co.'s wells that the pumping at one well affecting the water-level at another, occurred "Only in special cases, to a very limited extent"; the chief case being the Turnford and Cheshunt wells, which are three-quarters of a mile apart, between which "there is a very decided connexion," and "Amwell Hill, and Amwell Marsh also, to some extent, affect each other."[1]

Chadwell and Amwell Springs.

U. A. SMITH, writing of the Chadwell Spring (*see* p. 59), notes that "When the Spring ceased to overflow in 1898 the New River Company put down pumping machinery and pumped from a sump in the basin of the Spring into the New River, and farther lowered the water in the Spring. There is a line of wells extending up the valley for a distance of 1,200 yards from the Spring, and soon after the pumping . . . commenced the level of the water in these wells commenced to sink, and did not rise again until pumping had ceased." In 1901, some weeks after pumping had gone on, for some reason it was stopped: "immediately this occurred the water level in the wells commenced to rise, and continued to rise until pumping from the Spring was resumed when it again fell. This occurred in each well observed up to the most distant . . . and it is clear from the variation of that well that the effect extended much beyond."[2]

He also refers to the effect of pumping on the Amwell and Broxbourne springs, a fuller account of which is given on pp. 61, 62. But the notes here made (p. 32) seem to differ somewhat. He says of Amwell that the Amwell Hill and the Amwell Marsh Pumping Stations having been at rest for some days, the pumps were started. "Some of the springs were dried within half-an-hour of the start, small streams declined in their flow visibly, and some entirely dried up. After six hours pumping all the small streams were dry, and every spring was dry excepting one . . . the historical Emma spring, and even this had very materially declined in its flow. The investigation, however, did not extend beyond a radius of a quarter of a mile from one or other of the pumping stations."

Ware to Broxbourne.

U. A. SMITH has recorded the following cases of interference between wells in the Lea Valley.[3]

At Scots Hill and Warner Road, Ware, "wells are sunk some distance into the chalk, and their supply is very materially affected when pumping is going on at the New River Company's pumping station."

R. E. MIDDLETON (*ibid.*, p. 559) allows that these wells are probably affected "by the pumping at the Amwell End and Broadmead pumping stations." J. M. WOOD however tells me (1920) that he has never been able to trace any influence on neighbouring wells from pumping at Broadmead.

[1] *R. Comm. Metrop. Water Supply*, 1893. Minutes of Evidence, p. 3.
[2] Underground Water Preservation Association . . .. 1902 ? p. 31.
[3] *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 407.

A well at the brewery, Stanstead Abbots, 14 ft. deep, "used to contain about 4 ft. of water. . . . When the pumps of the Stanstead Pumping Station . . . a quarter of a mile away . . . are at work, the supply at once begins to decline, and the well has been drained quite dry."

At Broxbourne wells, including two at the gardens, have been drained. "The pumping at the New River Company's works at Broxbourne affects not only the shallow wells and the surface water, but also the deeper spring waters." Middleton (*ibid.*, p. 559) agrees that the effect of the New River pumping was felt at this distance.

According to U. A. Smith[1] the well at Haileybury College (*see* p. 175) was affected by the pumping at the Rye Common Well, a mile and 550 yards off. The well was originally 193½ ft. deep, "but in the Autumn of 1898, the water levels in the chalk had been so much lowered that the well had to be deepened . . 12 ft. This gave an adequate supply for the time being, but the pumping of the New River Company continued to increase and the quantity available in the Haileybury Well became less and less, and arrangements were made with the company to supply. "Very careful observations were made during the summer of 1898, and daily records were kept of the level of the water in Haileybury Well, with the result that when the pumping at Rye Common stopped, as it frequently did on Sundays, the water in the Haileybury Well was found to be higher on the Monday morning following. The total lowering of the water at this well during the period referred to was about 30 ft." According to J. M. Wood there was 29 ft. of water in the Haileybury well in June, 1920, notwithstanding the pumping in the Valley.

A small case of change in water-level, not from pumping, however, is noted by Dr. R. L. Sherlock, who says that at Ellenbrook and Nast Hyde (? St. Peter's Rural, St. Albans) the water-level, about 9 ft. down, was lowered to 12 when the ditches had been deepened.

[1] Underground Water Preservation Association . . ., 1902 ? pp. 29, 30.

MISCELLANEOUS.

RAINFALL, ETC.

Hertfordshire.

In Hertfordshire native effort has been singularly fruitful in meteorology. From its start in 1875 the Hertfordshire (first known as the Watford) Natural History Society has given us a continuous record of the monthly rainfall in the county, from a modest page recording it at 5 stations, in the year of its birth, increasing to 57 stations in 1914 (Report published January, 1916).

This record is the work of J. HOPKINSON, except for the years 1880 to 1887, when the REV. C. W. HARVEY contributed the reports, also harking so far back as 1840.

Moreover, Hertfordshire rainfall has been much in evidence before Royal Commissions, Parliamentary Committees, etc., and records, sometimes of a voluminous kind, are enshrined in the publications of those bodies.

A notable instance occurs in the Appendices to the Report of the Royal Commission on Metropolitan Water Supply, 1893, wherein is a Statement by J. HOPKINSON on Hertfordshire Rainfall, Percolation, and Evaporation (pp. 374-389) in which are given tables of Mean Rainfall in Herts. for half-a-century ending 31 March, 1892, and of Rainfall at the following places, Nash Mills (near Hemel Hempstead), 1834—1892; Kensworth, 1870—1892; Berkhamsted, 1856—1892; Gorhambury (St. Albans), 1860—1892; Rothamstead (Harpenden), 1853—1892; Hitchin, 1850—1892; Welwyn, 1872—1892; Bayfordbury (near Hertford) 1860—1892.

In the same volume R. E. MIDDLETON devotes pp. 645—655 to rainfall, with related matters following.

Other information is to be found in papers and discussions in the Proceedings of the Institution of Civil Engineers, and one may mention a paper by SIR J. EVANS On the Percolation of the Rainfall on Absorbent soils in vol. xlv., pt. iii., pp. 208—216 (1876).

No better general note can be given of the rainfall of Hertfordshire for a great number of years than by the following table, from HOPKINSON's paper on the Climate of Hertfordshire,[1] in which he says :—

"February, March, and April are the driest months . . . and July to November the wettest, October being much the wettest . . ."

"The rainfall is thus distributed between the seasons . . . spring, 5·41 ins. (21%); summer, 7·07 ins. (27%); autumn, 7·64 ins. (29%); and winter, 5·92 ins. (23%)."

[1] *Trans. Herts Nat. Hist. Soc.*, 1915, vol. xv, pt. 4, p. 204.

MEAN MONTHLY RAINFALL FOR 70 YEARS, 1840–1909, IN INCHES.

Months.	1840 to 1849.	1850 to 1859.	1860 to 1869.	1870 to 1879.	1880 to 1889.	1890 to 1899.	1900 to 1909.	1840 to 1909.
January	2·24	2·2	2·8	2·58	1·71	1·81	1·81	2·17
February	1·92	1·19	1·67	1·82	1·95	1·37	1·68	1·66
March	1·51	1·25	2·04	1·67	1·58	1·82	2·1	1·71
April	1·54	1·88	1·5	2·05	1·91	1·25	1·72	1·69
May	2·08	2·22	2·18	2·13	2·06	1·67	1·74	2·01
June	1·71	2·06	2·39	2·34	1·99	1·79	2·71	2·14
July	2·12	3·15	1·86	2·64	2·74	2·41	2·31	2·46
August	2·3	2·55	2·55	2·6	1·92	2·74	2·62	2·47
September	2·45	2·	2·47	2·64	2·6	1·95	1·44	2·22
October	3·34	3·22	2·39	2·56	3·18	3·09	2·91	2·96
November	2·85	2·23	2·1	2·76	2·84	2·56	1·91	2·46
December	1·76	1·55	2·16	2·18	2·26	2·31	2·39	2·09
Year	25·82	25·5	26·11	27·97	26·74	24·77	25·34	26·04

In one of his rainfall Reports HOPKINSON has dealt at some length with the question of percolation and the relation of rainfall to the water-contents of the Chalk,[1] and the following remarks (to p. 107) are taken therefrom. His figures for the areas of Chalk in the basins of the Colne and of the Lea have already been noticed (pp. 15–17). For the various tables for percolation, evaporation, etc., the reader is referred to the original. On them he bases the following deductions. It is convenient now to keep the various subjects together here, though some might fitly find a place elsewhere.

"The average winter percolation being nearly eight times as much as the average summer percolation, we see what a very great difference a small rainfall in the winter will make to the annual percolation. With about three-quarters the average annual rainfall, the percolation is reduced to nearly half the average, while there is only a reduction of one-fifth in the evaporation."

Applying the results to the catchment-basins of the Colne and Lea :— "With a total divergence of 17·05 ins. in the rainfall, there is a divergence of 8·20 ins. in the percolation, or rather less than half."

Dealing with the permeable and mixed beds of my classification (pp. 26–28), he takes the latter as half permeable and half impermeable, and then goes on to say, from the figures given, "7·72 ins. percolating per annum through the 148 square miles of permeable strata in the catchment-basin of the Colne and its tributaries above Harefield will yield about 45 million gallons per diem, and 6·08 ins. percolating per annum through the 224 square miles of permeable strata in the catchment-basin of the Lea and its tributaries above Feilde's Weir will yield about 54 million gallons per diem."

"To the amount of rain which percolates through the Chalk should be added that which runs off the surface of the impermeable strata. It is very difficult to form an estimate of this. There must be much more evaporation from the surface of impermeable beds than from the surface of permeable beds, for wherever water stands it must be exposed much longer to evaporating influences . . .

[1] *Trans. Herts Nat. Hist. Soc.*, 1896, vol. ix, pt. 2. Pages referred to 45–56.

than when it sinks beneath the surface. If we assume that impermeable beds yield with ordinary, or not very heavy, rainfall, half the amount of water that permeable beds do, we shall probably be very near the mark." On this assumption he concludes that "impermeable beds in the Colne area will yield about 12½ million gallons per diem . . . and in the Lea area will yield about 20½ million gallons." Adding these to the 45 and 54 square miles given above, "The total yield of the two areas with ordinary rainfall should therefore be about 132 million gallons per diem."

"But occasionally we have very heavy rain, which runs rapidly off impermeable beds; when excessively heavy it may even run off permeable beds, but that is rarely the case. It is as impossible to estimate the yield of these heavy falls, as it would be futile to rely upon them for our water-supply. They temporarily augment the volume of water in our rivers, sometimes to such an extent that they cause floods, but their effects soon cease."

"Even the estimated extra supply of 33 million gallons per diem derived from rain running off impermeable beds should not all be counted on as available for water-supply. It is essentially a winter supply, and in winter less water is required than in summer. We should therefore base our estimate of what we can rely upon on the available summer supply, and this is almost entirely derived from the rain which percolates through the Chalk in winter. . . ."

"The results given above are based on the average rainfall and percolation for a long period. But we cannot rely upon the average, or anything near the average, year by year," which question he discusses in some detail.

"In calculating the areas of the different catchment-basins (*see* above, pp. 15–17), and the probable yield of water from the rain which falls on them, I have assumed hitherto that the water-partings on the surface of the country correspond with the water-partings underground; that is to say that the rain which percolates in each catchment-basin keeps within that basin after it arrives at the plane of saturation in the Chalk; but there are grounds for inferring that such is not the case. Some of the rain which falls in the upper part of the Colne basin almost certainly is carried underground into the Lea basin, while none which falls in any part of the Lea is likely to get into the basin of the Colne." He regards this as partly owing to "the lowering of the plane of saturation of the Chalk in the Lea valley by the large amount of water pumped from great depths." But a considerable amount is pumped out of the smaller Colne basin also! Here we get into the realm of controversy, and Hopkinson ably supports the Hertfordshire contention against taking farther supplies out of that county.

With the above-described account I am in general agreement; but there are reasons for caution in accepting the details of the conclusions drawn from the observed facts: in this matter there must be, in engineering language, "a wide limit of deviation," owing to various causes. We do not yet know everything as to percolation into the Chalk; neither have we full data as to the areas taken up by permeable, impermeable, etc., beds. Moreover, few experiments have yet been made to test the direction of underground water in those places where

that is doubtful, as in the case of the swallow-holes in the upper part of the valley of the Colne ; but this is a work in which various difficulties would have to be overcome.

The above remarks of HOPKINSON's refer rather to percolation on the large scale. We may now turn to a short consideration of the means taken to measure it, which of course are on a small scale.

It has always seemed to me that the various experiments which have been made on the percolation of water through earth have had a weak point, in that they have been made through artificially prepared material, and that this, albeit done with the greatest care to reproduce nature, might fail to give results that did not differ considerably from what goes on in the ground.

MR. R. BENTLEY tells me that after a dry summer, when the first considerable rains of autumn came, small trial-holes have often been dug (at Upton, Slough) to find how far the newly-arrived rain penetrated into the ground. Within an area of a few acres, probably of much the same soil, surprising differences in the results were found, though tested in fairly open ground. Some plots no doubt had grown more hardened than others, whilst in some worms and moles had loosened the ground. Roots of elms and poplars travelled great distances just under the surface, and these kept ground dry and hard over areas that might seem beyond their influence.

It is well to put this in the words of one who has worked at the question, and to call attention to the fact that Hertfordshire is the only county in which what one may call a natural percolation-gauge has been made. This I had the advantage of seeing some years ago, with SIR A. D. HALL, then Director of the Rothamsted Experimental Station, and again in November, 1916, with his successor, DR. E. J. RUSSELL, and with DR. N. H. J. MILLER, and the following remarks are taken from a paper by the last :—[1]

"During the last sixty years numerous percolation and evaporation experiments have been made in this country and elsewhere. The method employed has been that originally used by Dalton."

"The Rothamsted gauges differ from those of Dalton in containing undisturbed soil. Soil which has been put into cylinders and subjected to the action of rain, will no doubt, as time goes on, acquire a more and more natural condition of consolidation, but we cannot know when this desirable condition is completed and can only take it for granted after a considerable time. The Barnfield gauges are free from this disadvantage, and as a means of measuring drainage, which is what they were mainly intended for, leave very little to be desired."

"The three Rothamsted drain-gauges, having each an area of 1/1000th of an acre, were constructed in the summer of 1870 by undermining the soil at the desired depths (20, 40, and 60 in. respectively), and inserting perforated iron plates beneath the soil to support it as the undermining proceeded. When this was completed, trenches were made on the other three sides of the blocks of soil, and these were then isolated by means of 4½ inch brick walls. The external soil was then returned."

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[1] *Journ. Agric. Science*, 1906, vol. i, pt. iv, pp. 377, etc.

"In 1874, leakage from the outside being suspected, the outsides of the walls of the gauges were exposed and covered with cement, and their thickness increased by another 4½ in. of bricks," and in 1879 one wall had an extra coating of cement.

"The drainage passing through the perforated iron plates which support the soil, falls into zinc funnels and flows from these into the measuring cylinders."

It is clear that these blocks are simply isolated parts of the natural soil and subsoil, and that what happens in them is what happens around them.

"The average yearly amounts of water percolating through 20, 40, and 60 in. of soil are very similar and amount to about 14 in., or approximately half the rainfall. The results obtained with the 20- and 60-in. gauges are indeed practically identical, whilst the 40-in. gauge yields on the average nearly 1 in. more." This is probably owing to the soil of the last being somewhat more permeable.

A table of the yearly amounts of drainage, from 1870 to 1905, shows that in the 20-in. gauge there was a variation from 5.74 in., in 1873-4 (with a rainfall of 21·69 in.), to 24·44 in 1878-9 (with a rainfall of 41·05 in.), the figures for the 40-in. gauge being 5·4 and 26·03, whilst those for the 60-in. gauge are 3·94 and 24·38.

"The yearly amounts of drainage show in each case . . . great variations, depending partly on the total rainfall and partly on the distribution of the rain during the year. Averages of several years arranged according to the magnitude of the rainfall show a regular increase in the amount of drainage . . . but in individual years there may be low drainage with relatively high rainfall, and *vice versa*."

"With regard to monthly percolation the average results . . . show that the maximum drainage occurs in November, that it gradually decreases until May, after which there is a regular rise to September, followed by a considerable rise in October."

By the kindness of DR. RUSSELL, I am able to give the following table, which is a continuation of Table IV. of DR. MILLER's paper.

RAINFALL AND DRAINAGE. MONTHLY AVERAGES FOR 10 YEARS, 1906–15. IN INCHES.

Months.	Rainfall, $\frac{1}{1000}$th acre gauge.	Percolation through soil.			Difference evaporated or retained by soil.		
		20-in. gauge.	40-in. gauge.	60-in. gauge.	20-in. gauge.	40-in. gauge.	60-in. gauge.
January... ...	2·37	2·02	2·09	2·06	·35	·26	·31
February ...	2·42	1·67	1·71	1·72	·75	·71	·7
March	2·67	1·68	1·67	·6	1·09	1·0	2·07
April	1·96	·51	·58	·5	1·45	1·38	1·4
May	2·01	·52	·56	·54	1·49	1·45	1·47
June	2·55	·68	·67	·65	1·87	1·88	1·9
July	2·17	·47	·5	·46	1·7	1·67	1·71
August	2·45	·79	·77	·83	1·66	1·68	1·62
September ...	1·48	·41	·4	·38	1·07	1·08	1·1
October	3·53	2·13	2·05	1·95	1·4	1·58	1·58
November ...	2·7	2·15	2·43	2·1	·55	·27	·6
December ...	4·13	3·88	3·83	3·75	·25	·3	·38

"An excess of drainage over the monthly rain has occurred on fifteen occasions, but always from November to March, and chiefly in January and February. On each occasion the excess has been observed in the case of the 40-in. gauge, whilst the 60- and 20-in. gauges have only yielded an excess on nine and seven occasions respectively. It is due either to the soil becoming frozen, or to an excess of water at the end of the month not having had time to percolate." It is to be remembered that the 40-in. gauge is the one with the highest average yield.

The effects of drought and of high rainfall on percolation and evaporation are considered and the composition of the drainage, as regards the amount of nitrogen and of chlorine is treated at some length, the object of the Experimental Station being, of course, agricultural.

Adjoining the percolation-gauges is a rain-gauge of the same area, that is, 1/1000th of an acre.

Dr. Russell writes (October, 1916) that "broadly speaking, the general conclusion is that half the water percolates and half evaporates from our land, which is uncropped," and he tells me that the only other installation of the sort that he knows of is in India.

Hopkinson's last contribution to the subject came to hand only just before this Memoir was sent to the printer, in January, 1920. "The Weather of the Year 1917 in Hertfordshire,"[1] continues his elaborate work, and, with three other papers in the same journal (published after his death), forms a fitting conclusion to the work of a life so largely given to the study of science in Hertfordshire.

Buckinghamshire.

This county differs from Hertfordshire in being somewhat neglected in the matter of local science. Presumably various Reports of Medical Officers of Health contain some records of local rainfall; but a continuous account from stations in various parts of the county can be found, I believe, only in the "Records of British Rainfall."

Mr. R. Bentley, an observer of long standing, has, however, kindly filled part of the gap with the following record, which may be taken as representing the south-eastern part of the county, in the lower part of the valley of the Thames, a tract of even lowland, over which there can hardly be any notable differences. The yearly average at Slough is approximately 24 in.; ten miles to the north, in the Chilterns, it is approximately 30.

Great falls of rain at one time, locally, occurred on 1st September, 1768; in September, 1880; on 10th September, 1885; 17th-18th July, 1890; and 9th-10th October, 1893. Mr. Bentley writes that only two days before receiving the Proof of this he scored a record, thanks to a thunderstorm: $1\frac{1}{4}$ inches of rain fell in an hour (5.30 to 6.30; real time).

Very rapid falls of rain in the district occurred on 16th July, 1875; 17th July, 1890; 1st October, 1899; 12th July, 1891; and 26th May, 1920.

The driest year was 1901, the wettest 1903.

[1] *Trans. Herts. Nat. Hist. Soc.*, 1919, vol. xvii, pt. 2, pp. 113–128, pl. iii.

Taking Slough as a representative place in South Bucks., the inches of rainfall measured there (at Upton, 78 ft. above sea-level) during the past 48 years has been as in the table.

Yearly Rainfall.

The sign + or — shows whether the year is above or below the average at Slough. The asterisks mark years of 366 days. The figures in brackets show the number of days on which ·01 in., or more, of rain fell.

1874 — .. 19·7	1897 + (159) 24·528
1875 + .. 26·69	1898 — (146) 17·918
*1876 + .. 28·565	1899 — (142) 21·858
1877 + .. 28·17	1900 — (165) 22·978
1878 + .. 28·215	1901 — (138) 16·868
1879 + (175) 35·255	1902 — (169) 20·366
*1880 + (148) 33·49	1903 + (185) 35·86
1881 + (149) 29·35	*1904 — (172) 23·376
1882 + (168) 28·64	1905 — (167) 20·297
1883 + (178) 24·63	1906 + (160) 26·125
*1884 — (140) 20·65	1907 — (177) 23·939
1885 + (171) 28·138	*1908 — (184) 24·07
1886 + (177) 28·455	1909 + (201) 25·274
1887 — (132) 20·24	1910 + (195) 27·831
*1888 + (172) 24·642	1911 — (166) 22·082
1889 — (176) 20·61	*1912 + (198) 30·772
1890 — (152) 19·495	1913 — (184) 22·781
1891 + (164) 24·92	1914 + (181) 27·238
*1892 — (139) 20·832	1915 + (165) 32·55
1893 — (129) 17·57	*1916 + (198) 31·758
1894 + (180) 27·878	1917 + (174) 26·366
1895 — (131) 22·248	1918 + (200) 29·947
*1896 — (157) 23·29	1919 + (193) 28·25

Rainfall Extremes, 1873—1918, *in inches.*

Months.	Wettest.	Driest.
January	4·54, 1877	... ·37, 1880
February	4·175, 1900	... ·022, 1891
March	3·97, 1914	... ·152, 1893
April	3·77, 1918	... ·035, 1893
May	4·12, 1878	... ·26, 1895
June	(*a*) 6·075, 1903	... ·32, 1895
July	5·605, 1880	... ·328, 1906
August	(*b*) 5·885, 1879	... ·472, 1911
September	6·012, 1918	... ·388, 1910
October	6·44, 1903	... ·718, 1919
November	4·35, 1916	... ·405, 1901
December	7·415, 1914	... ·435, 1873

(*a*) All of which fell between the 8th and the 19th.

(*b*) August, 1912, is close behind, with 5·85 in.

Various Notes.

In 1913 E. J. Salisbury noticed a possible connection between botany and water-level,[1] in describing "The struggle between furze and bracken, which is so well exemplified on Harpenden Common." These plants are found in many places "growing comparatively amicably together. . . . There was a time, and that quite recent, when such was the case at Harpenden; the bracken and furze both occurred here, but no marked change in the amount of either . . . was to be noticed, What, then, is the added factor which now loads the dice in favour of the bracken?"

"At one time there were on this common a large number of . . . slight depressions, which were sufficiently damp to grow luxuriant rushes at the bottom." But this has changed in the last two decades, the ground is drier, and the vegetation somewhat altered.

"That the water-level in Hertfordshire has been gradually falling for many years past is a well-known fact" (albeit there are folk who doubt it), and it seems that the above change shows "that this feature of the hydrography is reflected by the changes in the vegetation of Harpenden Common," and that it is "diminution in the water-content of the soil which has been the chief factor in causing the rapid increase of the bracken. This seems to be borne out by the direction in which the change has travelled. Obviously a lowering of the water-level will at first only affect the higher parts of the ground. . . Harpenden Common slopes from south to north, and this is the direction of the advance of the bracken and retreat of the furze."

"The spread of the bracken is further accelerated by the furze fires, which are constantly occurring," and which do not affect the bracken.

H. J. Wolfe figures an old wheel-well at the former manor-house, now Ameables Farm, 2½ miles from Harpenden. The well is 150 ft. deep. "The wheel is about thirteen feet in diameter; and to see it slowly turning on its massive oak axle-beam while the donkey plods along, is an interesting sight. It takes the animal ten minutes or a quarter of an hour to draw up the eighteen-gallon bucket." Other means have to be taken to raise the water, but the lord of the manor means to have the old well and its wheel kept.[2]

Dr. J. Mitchell has recorded that fatal effects resulted from the accumulation of sulphuretted hydrogen gas in a well at Applebury Street, near Cheshunt.[3]

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[1] *Trans. Herts Nat. Hist. Soc.*, vol. xv, pt. 1, pp. 71, 72.

[2] *Home Counties Mag.*, vol. iii, 1901, p. 300, and plate.

[3] *Proc. Geol. Soc.*, 1839, vol. iii, No. 65, p. 151.

SUPPLIES FROM SPRINGS.

The only case of a large supply taken from a spring in the two counties is that of the Chadwell Spring, used by the Metropolitan Water Board (*see* p. 55). Other spring-supplies have to do only with small places, and there are not many of these.

The few following notes are arranged alphabetically, by the names of places, under each county.

BUCKINGHAMSHIRE.

Brickhill, Bow.

Ordnance Map 220, new ser. Geologic Map 46, N.W.

A spring at Drakewell (presumably from Lower Greensand) is used for public supply.

In his Report on the Newport Pagnell Rural District (1912) Dr. W. W. E. FLETCHER says that "Bow Brickhill is supplied with water from three springs which have an abundant outflow . . . the springs are situated above the bulk of the houses in the village."

Edgcott.

Ordnance Map 219, new ser. Geologic Map 45, S.E.

According to the Local Government Board Return of 1915, R. A. B. MARSHAM supplies the parish from a spring near Edgcott, the yield of which is not known. From Drift ?

Gayhurst.

Various springs, here used for supply, are noticed on p. 43.

Lillingstone Lovell.

Ordnance Map 202, new ser. Geologic Map 45, N.E.

According to the Local Government Board Return of 1915, p. 246, Major J. B. DELAP supplies part of the parish from a "spring from rock (? Great Oolite). . . . The average daily quantity of water obtained is 8,640 gallons." The quality is good.

Linford, Great.

Geologic Map 203, new ser.

According to the Local Government Board Return of 1915, p. 247, W. UTHWATT supplies part of the parish from springs at Great Linford, the yield of which is spoken of as "unlimited." The quality is good. The source presumably is Great Oolite limestone.

Marsh Gibbon.

Ordnance Map 219, new ser. Geologic Map 45, S.E.

According to the Local Government Board Return of 1915, p. 246, the Ewelme Almshouses Trustees supply part of the parish by a "Spring from Oxford Clay in 'Stump Well Ground,' near Marsh Gibbon." Water of satisfactory quality.

The place is north of the village and is shown on the map, Bucks 21, in enclosure 235.

Marston, North.

Ordnance Map 219, new ser. Geologic Map 46, S.W.

A. C. G. CAMERON'S Notes.

The Selborne Spring (at the southern end of the village) is enclosed, with a pump. Water 4 ft. down. Overflows in adjoining field. Is much used. It is marked as chalybeate on the map (Bucks 23). For an analysis of the water, *see* p. 271.

Quainton.

Ordnance Map 219, new ser. Geologic Map 45, S.E.

A supply is got from a spring on Simber Hill (presumably from Portland Beds) Water good. Quantity ample. Local Government Board Return of 1915, p. 8. For an analysis of the water, *see* p. 272.

Stoke Goldington.

Geologic Map 203, new ser.

According to the Local Government Board Return of 1915, p. 247, the Water Committee supplies part of the parish from "(1) Spring at Stoke Goldington (above school); (2) Springs at Church Farm. The average daily quantity of water obtained is 18,000 gallons," of which source (2) is credited with 3,500. Quality good. For analysis, *see* p. 272. Another spring that is used is noticed on p. 44.

Taplow.

Local Government Board Return of 1915, p. 246.—Lord Desborough supplies part of the parish from a Chalk-spring. The site is on the side of the hill above Taplow Mills.

Water Stratford.

Ordnance Map 219, new ser. Geologic Map 45, N.E.

For the Buckingham Rural District Council. In pasture-land near main street. Information from J. B. Hill, Local Government Board. 354·14 ft. above Ordnance Datum. Average quantity of water available daily 3,900 gallons Presumably the water comes from Drift.

Westbury.

Ordnance Map 219, new ser. Geologic Map 45, N.E.

According to the Local Government Board Return of 1915, p. 247, Sir S. E. Scott, Bart., supplies the parish from "Spring at Westbury. The average daily quantity of water obtained is 15,000 gallons, and a further 24,000 gallons . . could be obtained." Quality very good.

The spring is in field 95 of the 25-inch Ordnance Map.

Weston Underwood.

Geologic Map 203, new ser.

According to the Local Government Board Return of 1915, p. 245, this village is supplied (by Lt.-Col. W. G. Bowyer) from a spring at the place, "from limestone overlying Upper Lias clay . . . The average daily quantity of water obtained is 2,250 gallons, and a further 8,000 . . . could be obtained." Quality satisfactory. For analysis, *see* p. 272.

The limestone must be Great Oolite, and presumably the underlying clay belongs to the Upper Estuarine Series.

Willen.

Geologic Map 203, new ser.

According to the Local Government Board Return of 1915, p. 246, the Trustees of Dr. Busby's Charity supply part of the parish from a limestone-spring (? Cornbrash) half a mile from the village, and the water is good.

HERTFORDSHIRE.

Eastwick.

Ordnance Map 240, new ser. Geologic Map 47.

Local Government Board Return of 1915, p. 277.

A. S. Bowlby supplies part of the parish by a "spring from gravel, Eastwick. The average daily quantity of water obtained is 1,000 gallons," and much more could be got. Quality excellent.

Rickmansworth.

The house at Moor Park, south-west of the town, is supplied from high gravel-springs, a little to the south.—Information on the spot, 1920.

St. Albans.

Local Government Board Return of 1915, p. 279.

The Earl of Verulam "supplies parts of parishes of Redbourn and St. Michael Rural," from a "Well, fed by a spring, near Pre Mill House," north-westward of the city. The daily average supply is 15,000 gallons. The quality is satisfactory.

Standon.

Ordnance Map 239, new ser. Geologic Map 47.

Dr. R. L. Sherlock, from information on the spot.

At Youngsbury Park, a spring of good water, at the Bath House, on the Rib, supplies the house with 4,000 gallons a day.

The large amount taken from springs near Ware by the Metropolitan Water Board has been noticed above, pp. 55, etc. This is by far the largest supply of the sort in the two counties.

SUPPLIES FROM WELLS.

The two counties do not possess a great number of very deep wells. There are only 10 that are 500 ft. and more in depth, and of these 5 are over 700, 3 over 800, and 2 over 1000. Two trial-borings, for coal, in Buckinghamshire, have gone to greater depths (*see* pp. 150, 160).

In Hertfordshire, however, there are several wells that yield a very large amount of water, those of the Metropolitan Water Board being, of course, most notable. Hertfordshire is one of those counties that has the power of supplying neighbouring districts (mostly Middlesex), its supply of water for domestic purposes being beyond its own need. To further extension of this sort the county has given strenuous opposition; but now it seems most unlikely that any attempt will be made to add to the supply of London by new wells in Hertfordshire. The controversy on this subject may be looked on as a thing of the past.

There are two companies which act for both counties jointly, and so may be noticed here, rather than under either county. Their wells, however, are described under the counties in which they occur.

Chiltern Hills Water Co.

This Company has a pumping station in the parish of Buckland, in Buckinghamshire (*see* p. 124), and another in the parish of Wigginton, in Hertfordshire (*see* p. 268).

It supplies part of Aylesbury and Tring Urban Districts and in part, or wholly, the parishes of Aston Clinton, Buckland, Drayton Beauchamp, Halton, Hartwell, Stone, Upper Winchendon, Waddesdon, Weedon, Wendover, Westcott and Weston Turville, in Buckinghamshire; and of Aldbury, Tring Rural, and Wigginton, in Hertfordshire.

The daily average supply is 607,985 gallons.

These particulars are from the Local Government Board Return of 1915.

The Rickmansworth and Uxbridge Valley Water Co.

Has wells in both counties, two in Hertfordshire (*see* Rickmansworth, p. 239) and one in Buckinghamshire (*see* Great Missenden, p. 149), besides another in Middlesex.

It supplies the following parishes, or parts of them, in Buckinghamshire:—Chalfont St. Peter, Charteridge, Denham, Fulmer, Great Missenden, Horton, Hughenden, Iver, Lee, Little Missenden and Wyrardisbury; and the following in Hertfordshire: Abbot's Langley, Bovingdon, Chorleywood, Flaunden, King's Langley, Rickmansworth, Sarratt, and Watford Rural; besides places in Middlesex. The daily average supply is 1,153,000 gallons. From Local Government Board Return of 1915, p. 210.

The works were established in 1887.

Most of the wells and borings have considerable geologic interest, as showing the nature and thickness of the various beds passed through. Beginning at the top of the scale, we have many records of great thicknesses of Glacial Drift, often pointing to the existence of channels cut out in the beds below. Then we have much evidence as to the depth to the Chalk, through Drift and Tertiary beds. In a few cases we get to know the full thickness of the Chalk and in rather more that of the Gault.

We learn also of local defects in the geologic succession, the absence of beds that occur elsewhere, and in some cases these defects are of a huge amount. In other words, we get much knowledge of the underground structure of the country, including the rising up of the older rocks.

A smaller set of wells are of special interest in regard to water-supply, from their large yields, and in some cases these are very large.

In the following lists what seem to be the more important wells from both points of view are named; but the geologists on the one hand will find many others of interest, and so also will those concerned with small supplies on the other hand. So many show details of Tertiary beds and the depth to the Chalk that they may be left out of this list.

Wells of Geologic Interest.

Buckinghamshire.

Beaconsfield, Nos. 1, 3. Thickness of Drift.

Boveney. Two borings showed Tertiary beds where they had not been mapped (hidden under gravel).

Buckland, No. 2. Through Chalk and Upper Greensand to Gault.

Charndon. Through Jurassic Rocks into Tremadoc Beds.

Cheddington. Wells through Chalk and Gault into Lower Greensand.

Fenny Stratford. The so-called Bletchley Boring. Through Jurassic beds possibly to old rocks.

Little Horwood. From Oxford Clay to Upper Lias.

Maid's Moreton, two. Go through Lower Oolites to Lower Lias.

Marsworth, No. 1. Through Chalk Marl, Upper Greensand and Gault into Lower Greensand.

Shenley Church End. From Oxford Clay through the Great Oolite Series to Northampton Sand.

Slough, No. 2. Deep boring through Tertiary and Cretaceous beds, to Lower Greensand.

Stone, No. 1. Through Upper and Middle Oolites into Great Oolite.

Stony Stratford, Nos. 1, 3. Through the Great Oolite Series to Middle Lias.

Hertfordshire.

Bishop's Stortford, Nos. 7, 19, 22, 23, 24, 26, show a great thickness of Glacial Drift.

Bushey, No. 2. Through Upper, Middle and Lower Chalk into Gault.

Cheshunt, No. 8. Deep Boring through Tertiaries, Chalk, Upper Greensand and Gault into Devonian.

Hitchin, No. 1. Through Chalk and Gault into Lower Greensand. This and Nos. 3, 5, 6, 7 show a great thickness of Glacial Drift.

Ickleford, Ippollitts, Langley, Stevenage No. 1, and Thorley No. 4 show a great thickness of Glacial Drift.

Standon, No. 2. A considerable thickness of Boulder Clay.

Tring, No. 1. Boring through Chalk and Gault into Lower Greensand.

Walkern, No. 1 shows a great thickness of Glacial Drift.

Ware, No. 2. Deep boring, through Chalk. Upper Greensand and Gault into Wenlock Beds.

Watford. Cannon Brewery. Said to go through the Chalk to Gault.

Little Wymondley. Both sections show a great thickness of Glacial Drift.

Wells of Interest in regard to Supply.

Buckinghamshire.

Amersham. Supplies a large district.

Buckland. One of the wells of the Chiltern Hills Water Co., which supplies a large district.

Burnham and Chesham Waterworks.

Datchet. Slough Waterworks supply a large district.

Maid's Moreton. Buckingham Waterworks. Two borings. Record of pumping.

Penn, No. 2. Record of water-levels.

Slough, No. 2. Deep boring. Water got from the Greensand.

Wolverton. Waterworks of the London and North Western Railway Co.

High Wycombe. Waterworks. A large supply.

Hertfordshire.

Great Amwell, Nos. 1, 2, 3. Wells of the Metropolitan Water Board.
Barley, No. 2. Long record of water -levels.
East Barnet, No. 2 and New Barnet, Nos. 1, 2. Wells of the Barnet District Water Co. Supply a large district.
Berkhampstead, No. 1, and Bishop's Stortford, No. 25. Waterworks.
Broxbourne. Well of the Metropolitan Water Board.
Bushey, Nos. 2, 3. Wells of the Colne Valley Water Co.
Cheshunt, No. 7. Local Waterworks. Nos. 3, 8. Wells of the Metropolitan Water Board.
Flamstead, No. 2. Record of pumping.
Hemel Hempstead, No. 4. Waterworks.
Hertford. Waterworks.
Hitchin. Waterworks. Large supply from shallow well in Chalk.
Hoddesdon. Well of the Metropolitan Water Board.
Redbourn. Borings yielding a large supply to watercress-beds.
Rickmansworth, No. 7. Waterworks. Pumping-tests.
Ridge. Tyttenhanger Well of the Barnet District Water Co.
St. Albans, Nos. 9, 10. Waterworks. Large supply.
St. Margarets, Rye Common. Well of the Metropolitan Water Board.
Sawbridgeworth. No. 2. Herts. and Essex Water Co. Supply chiefly to Essex.
Therfield, No. 1. Record of water-levels.
Ware, No. 2. Well of the Metropolitan Water Board. Six Local Waterworks.
Watford. Waterworks. A large supply.
Wigginton. One of the wells of the Chiltern Hills Water Co. Supplies a large district.

New Wells.

This heading has to do not merely with wells lately made, but also with older ones which have not been already recorded in print.

Probably very few published accounts of wells have escaped notice, and to many of these additions are now made. But the wells that have been hitherto unrecorded, or have had merely a passing note, are very many. In Buckinghamshire, indeed, most of the wells are practically new records.

The following list does not include many wells, of which but a very short or imperfect notice can be given, or which are very shallow.

Buckinghamshire.

Amersham, Nos. 1, 3; Beaconsfield, Nos. 1, 2, 3; Little Brickhill; Buckingham, No. 1; Buckland, No. 2; Burnham, Nos. 2, 3, 4; Cheddington, all; Chetwode; Datchet, No. 3; Ellesborough, No. 1; Fawley; Fenny Stratford, No. 4; Halton; Hanslope; Lane End; Little Horwood; Lillingstone Dayrell; Linslade, Nos. 3, 4, 6; Loudwater; Maid's Moreton; Great Marlow; Marsworth, Nos. 1, 2; Mentmore; Great and Little Missenden; Monk's Risborough; Newport Pagnell, two; Olney; Penn, two; Pounden; Shenley Church End; Slapton; Turville; Turweston; Weston Turville; Wing, two; Wolverton, No. 1.

Hertfordshire.

Albury, Nos. 1, 3; Little Amwell, No. 3; Barley, No. 1; High Barnet, No. 2; East Barnet, Nos. 1, 2; Little Berkhampstead; Bishop's Stortford, Nos. 7, 9, 18, 24; Bovingdon; Broxbourne, No. 4; Buntingford; Cheshunt, Nos. 2, 4, 5–7, 9, 13, 14, 17, 19, 20; Codicote, No. 1; Flamstead, No. 2; Great Gaddesden, Nos. 5, 6; Gilston; Little Hadham, Nos. 1, 5; Much Hadham, Nos. 1, 4, 8; Hatfield, Nos. 4, 5; Hemel Hempstead, No. 4; Hemsdon, Nos. 1, 3; Ippollitts, No. 2; Knebworth, Nos. 1, 2, 3; Letchworth; Northaw; North Mimms, Nos. 1, 2, 3; Rickmansworth, Nos. 8, 9, 10, 11; Ridge; Sacombe, No. 1; St. Albans, Nos. 4, 5; Shenley, No. 1; Standon, No. 2; Stanstead Abbots; Stevenage, Nos. 1, 6; Thorley, Nos. 2, 3, 4, 5; Ware, Nos. 1, 5; Watford, Nos. 2, 5; and Waterworks (6 or more). Watton, No. 2; Westmill; Widford, Nos. 1, 2, 3.

In the detailed account which follows, the wells of each county are arranged alphabetically, according to the places (towns, villages, parishes) in which they occur, and the numbers of the Ordnance and Geologic Map in which those places are to be found are given, those of the six inch maps in brackets. Unfortunately it sometimes happens that names given to sites are not in accordance with parish-boundaries : thus Tring station is not in Tring and Bletchley station is not in Bletchley. Such difficulties, however, are got over by means of cross-references and of the Index.

The spelling of the places follows that of the new series of Ordnance Maps ; but reference is sometimes made to the version given in older publications.

It has been usual to describe trial-borings, made for other purposes than water-supply, under a separate heading ; but there are comparatively few of these in the two counties, and for the most part these can be passed by as of no special interest here.

There are, however, two borings, made in search of coal, with no success in that matter, and these are of great depth, deeper indeed than any of the borings for water. It is well, therefore, to include an account of them, for they give much information as to deep-seated beds in parts where little was known before they were made.

Whilst one of them, at Steeple Claydon (p. 160), has been carefully recorded, of the other, at Little Missenden (p. 150), owing to the method of boring, few details have been kept, and so, for the most part, only generalizations can be given, except as regards the Silurian beds, to the great loss of geology.

Although not successful in finding coal, these borings are important in proving that in the two parts of Buckinghamshire where they were made, there is practically no chance of finding coal, and the same holds with the two borings for water in Hertfordshire, at Cheshunt and Ware (*see* pp. 203, 257), that have been taken deep enough to give evidence. Moreover, all four borings show that no supply of water can be got from beds below the Chalk.

DETAILS OF WELLS AND BORINGS.

BUCKINGHAMSHIRE.

Akeley.

Ordnance Map 219, new ser. (Bucks. 13 N.E.). Geologic Map 45, N.E.

1. For public supply. In the rear of cottages near the Schools, in the main street, 1875.

Information from J. B. Hill, Local Government Board.

382·39 ft. above Ordnance Datum.

A well of 3 ft. diameter and 7¾ ft. deep. Rest water-level 2 ft. down. Average quantity of water available daily, 3,000 gallons.

For an analysis of the water, *see* table, p. 281.

2. Three trial-borings made for the Buckingham Council. Presumably to test the ground, in regard to water-supply from gravel.

Others are in the parish of Maid's Moreton, *see* p. 144.

From W. Topley's Notes, 1889.

J. About 130 yards E. of road to Maid's Moreton and about 950 E. of S.E. from the Church. 390·76 ft. above Ordnance Datum. Water-level 3 ft. down.

A record that apparently belongs to this says clay to 66½ ft. and not through; 3 ft. of rock and then 4½ ft. of clay are said to have been found (? in this boring).

K. By the parish-boundary, on the road to Chackmore.

Mixed soil	3	33 ft.
Hard clay, chalky, no water	30	

M. At the junction of roads about 880 yards S.W. of the church. 422 ft. above Ordnance Datum. Water-level 3 ft. down.

Gravel. Water at 10 ft. ...	12	34 ft.
Clay	22	

Amersham.

Ordnance Map 255. new ser. (Bucks. 43). Geologic Map 7.

1. Brewery. Messrs. Wellers. Just northward of the church.

Made and communicated by Messrs. Isler and Co.

Water-level 9 ft. down.

Supply 4,300 gallons an hour.

	Thickness. Ft.	Depth. Ft.
Dug well [? the rest bored]		12
[River Drift] Gravel	5½	
[River Drift] Loose shingle	2½	
[River Drift] Gravel	4	24
[Middle] Chalk	87	111

2. Raans (? Reeves) Farm (for Lord Chesham).

Sunk and communicated by R. B. Paten, of St. Albans.

Shaft 186 ft. the rest bored.

Clay and stones	20	408 ft.
Chalk and flints, with layers of hard chalk	388	

3. Amersham Beaconsfield and District Waterworks Co. In the bottom of the valley at the southern end of the town.

Made and communicated by Messrs. Isler and Co.

Water-level 5 ft. down (? 15 ft., 1915).

Supply 15,000 gallons an hour. (? In 1911, 40,000 gallons a day).

	Thickness. Ft.	Depth. Ft.
Dug well (the rest a 15-in. boring) ...		6
[Drift] Clay-gravel	2	
[Drift] Gravel	7	15
Chalk. At 67½ ft. a hard layer of chalk rock met with, and continued about every two feet to 73 ft.	135	150

Amersham, cont.

In the Local Government Board Return of 1915 it is said that the wells go "through Chalk and Greensand"; but this must be an error. Average daily quantity of water available 300,000 gallons. Supplies also Chalfont St. Giles, Chesham Bois, Coleshill, Gerrard's Cross, Penn and Chipping Wycombe Rural.

For analyses of the water, *see* p. 277.

Barton Hartshorn.

Ordnance Map 219, new ser. Geologic Map 45, N.E.

For public supply. By the side of occupation-road and about 100 yards from ain road, 1886.

Information from J. B. Hill, Local Government Board.

343·96 ft. above Ordnance Datum.

Well of 4 ft. diameter, 7 ft. 7 in. deep. Drift ?

Rest-water level 1 ft. 10 in. down. Average quantity of water available daily 4,000 gallons.

Beaconsfield.

Ordnance Map 255, new ser. (Bucks. 47, E., 48, W.) Geologic Map 7.

T. W. Rammell, in his Report to the General Board of Health, in 1850, says that the supply was mostly from wells, which "for the most part are sunk through the gravel, a depth of some 12 or 13 ft." The water was said to be good, but varies in hardness, the amount, determined by Dr. L. Playfair (Lord Playfair), from seven wells and a spring, being from 2·73 (the next 16·5) to 27·5 degrees.

The later statement, in the Sixth Report of the Rivers Pollution Commission, p. 311, that the supply came from springs, must be a mistake.

1. Butler's Court, north-westward of the town, 1894. Not named on the newer map.

Made and communicated by Messrs. Le Grand and Sutcliff.

340 ft. above Ordnance Datum.

Water-level 178 ft. down.

		Thickness. Ft.	Depth. Ft.
Pit (the rest bored)			8
	Sandy mottled clay	16	
	Sandy mottled clay and large flints ...	6	
	Light-coloured sandy ballast [gravel] ...	3	
	Buff and red clayey gravel	10	
[Irregular	Light-coloured dry sandy gravel	15	
mass of	Red clayey and sandy gravel	9	
Drift.	Red sand	2	
? in	Red sandy gravel	2½	
channel]	White sand	13	
	Red sandy gravel and large white-coated flints	7	
	Brown and blue clay with pieces of chalk and flint·	8½	
	Large black flints	1½	101½
	Chalk and flints	3½	
	Chalk and flints, in hard and soft bands ...	87	
[Upper	Block chalk and flints	24	
Chalk]	Bands of hard and soft chalk and flints ...	36	
	Hard grey chalk	11	
	Thin bands of hard rock and grey chalk and flints	7	270

Beaconsfield, cont.

2. Hall Barn, south of the town, 1886.

Made and communicated by Messrs. Le Grand and Sutcliff.

Water-level 141 ft. down, August, 1886.

		Thickness. Ft.	Depth. Ft.
Pit (the rest bored)		—	9½
[Drift] Gravel		36½	46
[? Reading Beds]	Brown Sand ...	33	79
	Dirty gravel ...	16	95
	Flints	1	96
[Upper Chalk]	Chalk and flints ...	174	270
	Coloured sticky chalk	11	281

3. The Grange, 1911.

Communicated by the proprietor, Percy Chaplin.

Two borings, about 12 ft. apart.

In the first boring the tool jammed at the depth of 179 ft., of which 139 were chalk and flints. The site is over the channel of an old swallow-hole, which became inactive when the valley, a little to the north, was enough eroded.

The tool suddenly dropped into a large cavity, and on trying to regain the gear the cable broke and the gear was lost, and another boring had to be made.

In the second at 98 ft. down the tool dropped a clear 10 ft. Then a depth of very soft detritus was passed through before the chalk was touched again.

Lined to 162 ft. with 6 in. tubes. Suction tubes at 196–204.

Water-level, when made, 166 ft. down, or 234 above Ordnance Datum.

Yield over 1,800 gallons an hour.

		Thickness. Ft.	Depth. Ft.
[Irregular ? mass of Drift, in channel]	Clay	12	
	Clay and fine sand	28	
	Chalk and flints	58	
	Cavity	10	108
[? Reading Beds]	Sand and clay	52	160
[Upper Chalk]	Hard chalk and flints	141	301

Bletchley.

Ordnance Map 220, new ser. (Bucks. 15, S.W.) Geologic Map 46, N.W.

Two shallow wells. From A. C. G. Cameron's notes.

1. Farm on Whaddon road, near the Swan inn. Dug in gravel, 10 ft.

2. Orchard, at cottage 10 yards south of Swan inn. Dug in clay, 40 ft.

Railway Station, *see* Fenny Stratford.

Bourne End, *see* Wooburn.

Boveney.

Ordnance Map 269, new ser. (Bucks. 55). Geologic Map 7.

Trial-borings, made by the Grand Junction Waterworks Co. On Dorney Common. (Both just in Boveney). 1887.

Communicated by A. Fraser, Engineer to the Co., and (in the case of No. 1) by F. Drew (with specimens).

1. At the eastern side of the Common, about 135 yards N. of Tilson Bridge and over a mile E. of the church.

Over 68½ ft. above Ordnance Datum.		Thickness. Ft.	Depth. Ft.
Soil		2	2
[River Gravel 27 ft.]	Dirty Ballast	1	
	Rough clean ballast	1	
	Rough clean ballast and sand (with (water)	8	
	Rough clean ballast	15	
	Ballast and sand (water)	2	29
Blue [London] Clay. [Specimen of sandy clay, with green grains and traces of shells=Basement-bed] ...		30	59
[Reading Beds, 33 ft.]	Red marl	3	
	Yellow and grey marl [mottled] ...	15½	77½
	Brown sand	14½	92

Boveney, cont.

Mr. DREW's account differs in making the gravel and sand 29 ft. and the Reading Beds as follows, giving a total depth of 100 ft. :—

Mottled clay [specimen of grey and mottled] ...	4
Loam	35

2. At the southern end of Dorney Common, about 55 yards north-eastward of the bridge (over Cress Brook), for the track to Boveney, and nearly half a mile S. of Manor Farm.

67¾ ft. above Ordnance Datum.

		Thickness. Ft.	Depth. Ft.
Soil		2	2
[River Gravel, 19 ft.]	Dirty ballast	2	
	Clean ballast	17	21
[London Clay 20 ft.]	Black clay	14	
	Black sandy clay	6	41
[Reading Beds 78½ ft.]	Grey marl, clayish (mottled)... ...	10	
	Grey and red marl, clayish (mottled)	6	57
	Wet stiff brown sand	19	76
	Brown clay	½	
	Wet stiff brown sand with stones ...	18	94½
	All coloured stiff clay (mottled) ...	22 ?	116½
	Small flints with clay. One large flint	3 ?	119½
Soft chalk and small flints...		4½ ?	124

Brickhill, Bow.

Ordnance Map 220, new ser. (Bucks. 15, S.E.) Geologic Map 46, N.W.

1. A. C. G. CAMERON notes that a well sunk through sands, sometimes rocky, to the depth of 85 ft. has yielded a good supply.

2. A trial-boring for water in the field by the western edge of the wood called Kiln Ground, and about 1,250 yards south-eastward from All Saints Church, about 1900 ? Little water was found.

Lower Greensand. Sand about 74 }
? Oxford Clay. Clay about 11½ } 85½ ft.

Brickhill, Great.

Ordnance Map 220, new ser. (Bucks. 20, N.E.) Geologic Map 46, N.W.

A well belonging to the Bletchley Urban District Council supplies part of Bletchley Urban District, Great and Little Brickhill, Walton and Woughton on the Green. It is in Lower Greensand. The supply is 10,000 gallons a day ; but the Council gets 120,000 from a well in Lower Greensand at Sand House, in the northern part of the parish of Heath and Reach, in Bedfordshire. The hardness of the Brickhill water is 6·1°. . . Local Government Board Return of 1915, pp. 19, 20.

Additional information from J. B. HILL, Local Government Board. Well at Black Dog Spinney (not marked on map), about 250 yards W.N.W. of Stockgrove Farm, 400 ft. above Ordnance Datum, 30 ft. deep. Water-level 15 ft. down.

The following notes from J. EUNSON (1890), refer to the above. In sinking they came on an old disused well, and had some trouble in getting down to water. At 15 ft. deep they were pumping 6,500 gallons an hour, the full power of the pumps. They pumped for 199 hours at that level, without altering the inflow in the slightest. They then bored, still in sand, for 8 ft., to a mixture of clay and sand, and at 26 ft. down (395 above Ordnance Datum) were in Oxford Clay. The old well was found to have been a public one.

Brickhill, Little.

Ordnance Map 220, new ser. (Bucks. 15, S.E., 20 N.E.) Geologic Map 46, N.W.

1. Trial-boring, on the north-eastern side of Watling Street, nearly half a mile a little E. of S. of Buttermilk Farm. 1889.

Brickhill, cont.

Made and communicated by Messrs. Le Grand and Sutcliff. (Notes on specimens in brackets.)

		Thickness. Ft.	Depth. Ft.
[Boulder Clay.]	Yellow clay	4	4
	Boulder clay (brownish)	13½	
	Clay and sand (sandy clay)	4	
	Boulder clay (grey)	2¼	
	Rock (grey limestone, with pyrites; a boulder)	¼	
	Boulder clay (grey, rather sandy) ...	2	26
[Lower Greensand.]	Green sand (reddish-brown) and ironstone	19	
	Green sand (brown) and ironstone ...	3	
	Green sand (yellowish-brown)	32	
	Brown sand and ironstone	11	
	Brown loam (compacted, slightly clayey sand) with ironstone occasionally ...	42	133
? Oxford (grey clay)		12	145

2. Trial-boring. About a third of a mile S.S.W. of the church, in a field on eastern side of lane close to parish-boundary. 1888.

[Lower Greensand]. Sand	10	10 } 45 ft.
[Oxford] Clay	35	}

Brill.

Ordnance Map 237, new ser. (Bucks. 27, S.W.) or Oxford Geologic Map.

Coldharbour Farm, Rid's Hill, N.E. of the village. 1902 ?

Communicated by J. T. Onley, Steward of the Chandos Estates.

Clay, with vein of sand and what appears to be ironstone, 43 ft.

Buckingham.

Ordnance Map 219, new ser. (Bucks. 13, S.) Geologic Map 45, N.E.

1. Anglo-Swiss Milk Company. In the meadows by old water-mill, about a quarter mile above railway-station. 1899.

Bored and communicated by Messrs. Duke and Ockenden.

A 12-in. bore to 18½ ft.; then 10 inch to the bottom. Lined to 57¾ ft.

Surface water stood 3 ft. down. Water in borehole 3½ ft.

		Thickness. Ft.	Depth. Ft.
[Drift] ...	Gravel sand, *and large boulders* ...	14½	
	Sand with loose rock	4½	19
[?Great Oolite.]	Rock, with layers of clay (6 to 12 in. thick). Small quantity of water at 30 to 33 ft	28½	47½
Black clay		10½	
Clay intermixed with sand		1	59
Undescribed (? clay). At bottom there appeared to be a cavity. Tool went down. Water came in		2	61
Blue clay		9	70

2. Gawcott, S.S.W. of the town.

From the Local Government Board Return of 1915, with an addition.

Wells 4½ ft. deep on Oolitic gravel yield, to the extent of 3,000 gallons a day. For the town-supply.

For analysis, *see* p. 280.

Buckland.

Ordnance Map 238, new ser. (Bucks. 34, N.) Geologic Map 46. S.W.

1. Buckland Wharf, S.E. of the village.

A. C. G. Cameron's Notes.

Chalk, 28 ft.

Water stands 16 ft in the well.

At Quarry House, by the roadside between this and Tring it is 90 ft. to water.

In summer these wells and those at Aston Clinton are dry.

For analysis of the water, *see* p. 283.

2. Chiltern Hills Waterworks. About 2¼ miles S. of E. of the village.

Communicated by S. C. Homersham, with further information from Mr. Callon and R. B. Paten.

Buckland, cont.

650 ft. above the level of the sea.

Shaft 235½ ft. (? 4 shafts), the rest bored (5 borings). About 1,200 ft. of adits driven near the base of the shaft.

Normal water-level from 469 to 512 ft. above Ordnance Datum.

Yield 250,000 gallons a day. Later, the Local Government Board Return of 1915 gives 261,000. According to Mr. Callon five borings, about 70 ft. below the adits, do not yield more than 50,000 gallons in 24 hours.

	Thickness. Ft.	Depth. Ft.
Chalk without flints ... ... about	285½	285½
Grey chalk ... ... about	159	444½
Upper Greensand [? including either part of the Chalk Marl, or of the Gault]	57	501½
Gault	16½	518

According to a drawing shown me by Mr. Callon, the shaft goes through the "hard bedded chalk" of my classification (for Bucks, etc.) into the "white blocky chalk" that overlies the Totternhoe Stone.

For analysis, *see* p. 283.

Burnham.

Ordnance Map 255, new ser. (Bucks. 52, SE.) Geologic Map 7.

1. Brewery (? Rose Brewery, on the eastern side of the main street. About 180 ft. above Ordnance Datum).

Sunk and communicated by R. B. Paten.

Shaft 70 ft., the rest bored.

Clay and sand [? partly Reading Beds]	80	180 ft.
Chalk and flints	100	

An account from Messrs. Isler and Co. of a well at Messrs. Brown and Terry's Brewery (probably the same as the above) differs slightly, making the shaft 78 ft. and the boring (through chalk and flints) 51 ft. The water-level is 89 ft. down and the yield 1,000 gallons an hour.

2. Burnham, Dorney and Hitcham Waterworks. Within 200 yards of the cross roads in the village.

Made and communicated by Messrs. Isler and Co.

Apparently 4 boreholes, of which there are records of 3.

Shaft 102 ft., then an 11-in. boring.

Water-level 89 ft. down.

Supply 8,000 gallons an hour.

Clay and sand	80	252 ft.
Chalk and flints	172	

According to the Local Government Board Return of 1915 the bored wells are 300 ft. deep. The average daily quantity got is 200,000 gallons. Supplies also parts of Farnham Royal and Taplow.

3. Waterworks. Second boring ?

80 ft. of 13¼ in. tubes from the surface.

Water-level, rods out 96 ft., rods in 95.

		Thickness. Ft.	Depth. Ft.
Made ground		4	4
[River] Gravel		13	17
Yellow [London] clay		17	34
[Reading Beds, 43 ft.]	Red marl	3	
	Sand stone	1	
	Red marl	18	
	Black clay	10	
	Mottled clay	7	
	Greensand	1	
	Green-coated flints	3	77
	Chalk and flints	17	
	Hard chalk	13	
[Upper Chalk, 273 ft.]	Chalk and flints	5	
	Hard chalk	36	148
	Chalk and flints	151	
	Bed of flints	4	303
	Hard chalk	47	350

The third borehole gave practically no supply.

Burnham, cont.

4. Waterworks. Fourth Boring.

70 ft. of 13¼ in. tubes from 4 ft. down.

Water-level 95 ft. down.

Supply 8,844 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Loamy soil		3	3
[River] Gravel		15	18
[London Clay and Reading Beds.]	Brown clay	29	
	Dark blue clay	9	
	Blowing sand	1	57
	Dark blue clay	5	
	Mottled clay	6	68
	Loamy sand	3	
	Green-coated flints	1	72
[Upper Chalk, 228 ft.]	Chalk and flints	167	239
	Hard chalk	14	253
	Chalk and flints	47	300

Calvert, *see* Charndon.

Chalfont St. Peter.

Ordnance Map 255, new ser. (Bucks. 48, E.) Geologic Map 7.

3. Wells from the notes of A. H. Noble.

1. Brawlings, over 1¼ miles N.N.E. of village. 168 ft. deep, bricked for 40. At least 20 ft. of water.

2. The Colony. Over a mile north of the village.
140 ft. deep, bricked for 30. 20 ft. of water (which had been rising). Yield 10,000 gallons a day, lowering the level 6 in.

3. Gold Hill. W.S.W. of the church. N.E. of the hamlet and just at the edge of the gravel.
120 ft. deep (through Reading Beds to Chalk). 90 ft. to water, and at least 30 of water.

Charndon.

Ordnance Map 219, new ser. (Bucks. 22, N.W.), Geologic Map 45, S.E.

By Calvert Station, Great Central Railway. Western Boring (for the eastern, *see* Steeple Claydon), in brickfield, over 300 yards E.N.E. of Charndon Lodge Farm, 1905, to 445 ft. 8 in. Deepened 1911.

Iron and Coal Trades Review, 1st September, 1911, p. 316, and Dr. A. M. Davies and J. Pringle. *Quart. Journ. Geol. Soc.*, 1913, vol. lxix., pp. 308, 309, 326—329. Only salt water got.

At the bottom of a pit, about 70 ft. deep, ? over 220 above Ordnance Datum.

		Thickness. Ft. Ins.	Depth. Ft. Ins.
Oxford Clay.	Dark blue clay, very hard	5 0	5 0
	,, ,, ,, ,, with sand	7 10	12 10
	Grey sandstone and clay. Water 2 ft. 7 in. down	13 3	26 1
	Stiff dark blue clay, with large stones [septaria] overflow, about 6 gallons an hour	4 4	30 5
	Stone, very hard	1 8	32 1

Charndon, cont.

		Thickness. Ft. Ins.	Depth. Ft. Ins.
	Dark grey rock	2 7	34 8
	,, ,, and blue clay	2 10	37 6
	,, ,, very hard	1 8	39 2
	Limestone	1 11	41 1
	,, with thin beds of clay and shale ...	2 0	43 1
	Grey limestone and blue clay. Overflow 8 gallons an hour at nearly 57 ft., 12 gallons at bottom	16 8	59 9
Oolites ...	Grey limestone and shells	2 3	62 0
	Grey limestone	1 6	63 6
	Grey limestone and shale	35 0	98 6
	Green shale and (limestone?)	9 10	108 4
	Grey limestone	2 3	110 7
	Grey limestone and red sandstone [?] Water overflowed (at the rate of 24 gallons an hour from the bottom)	21 11	132 6
	Grey sandstone [?] and sand. Water overflowed	2 6	135 0
	Cores not drawn. Water overflowed ...	5 6	140 6
	Soft rotten shale / Cores not drawn } Water 2½ feet down ...	8 6	149 0
	Loamy sand and rotten shale	2 0	151 0
	Cores not drawn	10 0	161 0
	Shale 5½ feet, with ironstone bands. Grey sandstone. [Some error, as it continues with cores not drawn	4 0	165 0
	Hard grey sandstone. Water overflowed ...	2 3	167 3
	Grey sandstone, 1 ft. [?what else]	6 0	173 3
	Soft rotten shale. Water overflowed ...	5 6	178 9
	,, ,, with ironstone-bands ...	19 3	198 0
Lias ...	Soft rotten shale	6 0	204 0
	Undescribed, and core with ironstone-bands, 6 in.	14 0	218 0
	Soft rotten shale, with ironstone-bands. Core of 7 ft. at top, of 7½ at bottom	24 0	242 0
	Shale, with ironstone-bands, core 5 ft. ...	7 6	249 6
	Blue shale, with ironstone (2 ft. 3 in.) ...	5 6	255 0
	,, ,, ,, balls [septaria] ...	7 6	262 6
	Soft shale, with hard grey stone at about 284½, 300½, and 306½ ft.	49 6	312 0
	Undescribed. Water overflowed, 45 gallons an hour at 317 ft. 10 ins. ? was 35 ft. down lower and 30 ft. down lower still. Struck gas at 380 ft.	68 0	380 0
	Soft red shale	2 0	382 0
	Undescribed. Gas at 396 ft.	?29 0	?411 0
	Mottled shale. Gas very strong	2 0	413 0
	Undescribed. Heavy pressure of gas at about 423½ ft.	?15 5	?428 5
Tremadoc	Mottled shale	?4 7	433 0
Beds.	Blue shale	10 7	443 7
	Jointy blue shale and ironstone bands 2 ft. 8 in. [?]	2 1	445 8
	Deepened in 1911, when cores like those in the Steeple Claydon boring (p. 160) were got, with fossils in places	203 4	649 0

The bottom will therefore be about 515 ft. from the surface of the ground, the pit being about 70 ft. deep, not 90 as given in the described account.

Dr. DAVIES writes (1915) that the *ironstone* often noted in the Lias, is probably a mistake. These beds are most likely septaria, or clayey limestone, as nothing like ironstone was found in the neighbouring trial-boring in the parish of Steeple Claydon, *see* p. 160.

Charndon, cont.

2. According to a letter from S. H. Looker, Clerk to the Council (1912), there were then only two wells in Charndon, one at the southern end of the village, which gave the sole supply until 1901. Originally a shallow spring, on the side of a sandy hill, the occupier of the land deepened it about 25 years ago, and bricked the inside, making it into a well. All the village came to it for water, some from nearly three-quarters of a mile.

3. Same authority. In 1901 the Buckingham Rural District Council sank a well and put up a windmill-pump, which supplies the village. The well is 30 ft. deep, and the water comes in at the depth of 24 ft.

Information from J. B. Hill, Local Government Board, adds that the pump is in pasture-land, about 150 yards from main road, 308·6 ft. above Ordnance Datum, the well is of 5½ ft. diameter. The water-level fluctuates considerably. ? Drift. Average quantity of water available daily, 6,000 gallons.

For analyses of the waters, *see* p. 284.

Cheddington.

Ordnance Map 238, new ser. (Bucks. 29, NE.). Geologic Map 46, SW.

1. Coprolite-pits (formerly worked). A quarter mile south east of railway-station : a brickyard since ? 1874.

Information from workmen on the spot.

Dug 90 ft., and bored 60 or 70, through clay (Gault) to rock (Lower Greensand) and water. Thickness of Gault about 150 ft.

2. Engine-house by the canal at the first lock north of the road to Ivinghoe.

Information from Mr. Wilkinson of Leighton Buzzard.

309 ft. above sea-level.

About 150 ft. deep. Water said to come from Lower Greensand.

3. Parsonage.

Made and communicated by J. Dalton.

Shaft 100 ft., the rest bored.

Water rose 100 ft. in 10 minutes [from the bottom].

[Gault]. Clay, hard and lumpy, with coprolite [phosphatic nodules] at 8, 40 and 185 ft. [? to sand] 195 ft.

4. Sections of the London and Birmingham Railway. By L. L. B. Ibbetson, 1847. No. 10. MS. Drawing in the Geological Survey Office.

Gault (*Belemnites Listeri*)	160		
Lower Greensand { Quick sand	6	}	169 ft.
Lower Greensand { Rock	3	}	

5. Railway Station. Communicated by T. M. Smith ?

Well of 3 ft. 8 in. diameter, to the bottom of the Gault, starting some way in the embankment, then a boring. The water taken from the surface (above which it rose) was good ; but when pumped, bad and unfit for domestic use.

Gault (from below natural surface)	71½	}	121½
Lower Greensand	50	}	

Another note says 109 ft. of blue clay, to sandstone.

6. For the Cheddington Water Works Trustees. For the supply of the village 1,200 yards south-westward from the church and 2,100 yards from the Canal Co.'s boring. Communicated by the Local Government Board.

400 ft. above Ordnance Datum.

Water-level at commencement of pumping 243 ft. above Ordnance Datum : at cessation of pumping 236. Returns at once to original rest-level on cessation of pumping. The Local Government Board Return of 1915, p. 246, gives the average daily quantity of water got as 5,000 gallons : more could be got.

Cheddington, cont.

		Thickness. Ft.	Depth. Ft.
Soil.	Clay and flints	10	10
	Chalk	30	40
[Chalk Marl]	Sandy chalk	20	60
	Chalk and clay	30	90
Gault.	Blue clay	220	310
[Lower] Greensand	... ...	26	336

According to Messrs. Sands and Walker, it is an 8-in. boring, lined with steel tubes, the bottom 20 ft. being perforated. The yield was tested (1906) up to 45,000 gallons a day. More could be got, but only 15,000 were wanted.

For analysis of the water, *see* pp. 284, 285.

Chesham.

Ordnance Map 238, new ser. (Bucks. 39, S.W.). Geologic Map 7.

1. The Thorn. About two miles N.N.E. from the town. Made and communicated by R. B. Paten.

About 548 ft. above Ordnance Datum.

Shaft 180 feet, the rest bored.

Clay and gravel	40	310 ft.
Chalk and flints	270	

2. Waterworks. Berkhampstead Road. 1882.

About 350 ft. above Ordnance Datum.

Sunk and communicated by R. B. Paten.

Shaft 5 ft., the rest bored.

Soil or mould	2	235 ft.
Marl [? Alluvium]	2	
Clay and stones [? Alluvium or Gravel]	3	
Chalk, flints, and hard chalk	228	

From information on the spot. Pit about 8 ft. Boring, lined (or cylinders) [? to] 40 ft. The rest open. Water chiefly from rock at the bottom. Overflowed at first. When pumping 10 hours a day the rest-level about 17 ft. down, and practically not altered by pumping. Supply about 200,000 gallons a day.

For an analysis of the water, *see* p. 285.

3. The following information is from Dr. R. L. Sherlock:

At Chesham Moor and lower down the valley-bottom, near Weirhouse Mill, are many borings, the water from which overflows into the watercress-beds.

At Blackburn, Chesham Vale, it was about 25 ft. to water; but in December the water sunk too low for pumping.

Chesham Bois.

Ordnance Map 238, new ser. Geologic Map 7.

Watercress Beds (?). In the valley-bottom northward of the village (which is in Bucks. 43, N.W.) just above Chesham Sewage Works (Bucks. 39, SW.).

Wells (? borings) about 120 ft. deep, through 10 ft. of gravel into Middle Chalk.

Water met with at the depth of 81–87 ft. Overflows.

Chetwode.

Ordnance Map 219, new ser. (Bucks. 17, NE.). Geologic Map 45, NE.

Manor House, 1914.

Bored and communicated by Messrs. Le Grand and Sutcliff. Yield, none.

		Thickness. Ft. In.	Depth. Ft. In.
Made Ground		5 0	5 0
	Brown clayey sand	3 6	—
	Mottled clay	0 6	—
[Boulder Clay and Oxford Clay].	Blue clay	*a*27 0	36 0
	Loamy sand, moist	8 0	44 0
	Clay, slightly sandy	1 0	—
	Blue clay	7 6	52 6

Chetwode, cont.

		Thickness. Ft. In.	Depth. Ft. In.
	Rock	1 0	—
	Clay and layer of rock	7 0	—
	Rock	*b* 3 0	63 6
	Green clay	2 3	—
	Rock	*c* 1 0	66 9
	Clay	1 3	—
	Rock	2 0	—
	Clay	1 0	—
	Rock	2 6	—
	Clay	3 6	—
	Rock	4 0	—
	Clay	0 3	—
	Rock and thin layers of clay ...	17 9	—
[Jurassic Limestones, etc.].	Rock	1 0	100 0
	Rock with very thin layer of clay	5 0	—
	Rock	3 0	—
	Clay	2 0	—
	Rock	3 0	—
	Clay	0 2	—
	Rock	*d* 0 4	113 6
	Rock with 2-in. band of clay ...	*e* 1 0	114 6
	Clay	15 0	—
	Rock	3 0	—
	Clay	1 0	—
	Rock	1 6	—
	Clay	5 6	—
	Rock	6 6	147 0
	Black clay	20 6	—
	Blue clay	45 6	—
	Rock	0 6	—
	Clay	2 6	—
	Rock	0 6	—
	Clay	1 6	—
	Rock	0 6	—
	Clay	0 6	—
[Lias]	Rock	2 0	—
	Clay	0 6	—
	Rock	1 0	—
	Clay	0 6	—
	Rock	2 6	—
	Sandy clay	11 0	—
	Rock	3 6	—
	Blue clay, not sandy	21 0	260 6

Another account differs in some details, as follows :—

Bed marked *a* given as 26 ft.
,, *b* ,, 2 ft. 6 in.
,, *c* ,, 1 ft. 6 in.
,, *d* ,, 10 in.
,, *e* omitted.

The total given as 260 ft. ; but adds up 261.

Chilton.

Ordnance Map 237, new ser. (Bucks. 32. NW.). Geologic Map 45. SE.

The wells at Chilton Grove Farm, north-west of the village, seem to get a supply from Kimmeridge Clay. They are of interest because of the outbreak of enteric fever in Marylebone in 1873 having been traced to the water of the farm-well, *see* p. 95.

Claydon, East.

1. Waterworks well at eastern part of village.

2. Winslow Road Station, eastward of the village, 1914.

Well 30 ft. in Oxford Clay, according to H. PERKIN, Assistant Engineer, Great Central Railway, who adds "I am told that about half a mile to the east of the station, towards Winslow (and therefore in that parish) water has been obtained by boring in several wells and the depth has not been more than 120 ft."

Claydon, *see* Steeple Claydon.

Crendon, *see* Long Crendon.

Datchet.

Ordnance Map 269, new ser. (Bucks. 56). Geologic Map 7.

1. For the Slough Waterworks Co. Experimental boring, 1882 ?

J. LOBLEY, *Proc. Geol. Assoc.*, vol. vii, pp. 391–395. (The words in these, brackets from an account commmunicated by Messrs. S. F. BAKER AND SONS.)

Boring 3 ft. diameter (?). Water overflowed.

		Thickness. Ft. In.	Depth. Ft. In.
Soil		1 0	1 0
[Valley Drift] ...	Brickearth	3 0	—
	Brickearth, more sandy ...	3 6	—
	Gravel, with sand	11 6	19 0
London Clay, 20 ft.	Blue clay	12 0	—
	Blue sandy clay...	3 0	—
	Blue clay (mottled clay) ...	5 0	39 0
Reading Beds, 78 ft.	Red and yellow mottled clay (Red clay)	9 0	—
	Blue and brown mottled clay ...	5 0	—
	Brown clay (and sand) ...	14 0	—
	Yellow sandy clay	1 0	—
	Brown sand	16 0	84 0
	Dark sand	4 0	—
	Sandy clay	2 0	—
	Light-coloured sand	3 0	93 0
	Mottled clay	23 0	—
	Flints, to Chalk	1 0	117 0

2. Slough Waterworks. Five furlongs north-west of church. 1885. 63 ft. above Ordnance Datum.

Communicated by E. O. SECKER.

Cylinders down to 5 ft. into the Chalk, then shaft enlarged, down to the depth of 160 ft. The rest a bore, of 18 in. diameter. Supply abundant.

Original water-level 3 ft. down. In 1889 pumped down to about 60. Most of the water from a bed of flints about 160 ft. down.

When the sinking (not the boring) in the Chalk was finished, a 12-in. pump of 3-ft. stroke, working about 28 strokes a minute, just kept the water back. Since then the yield has increased.

The section differs only in slight details from that of the trial-boring, the chief points being as follows.

The soil is made $2\frac{1}{2}$ ft.

The "flints" at the base of the Reading Beds is given as yellow and blue clay.

The depth to the Chalk comes to $118\frac{1}{2}$ ft.

The depth in the Chalk is $246\frac{1}{2}$, and consequently the total depth is 365 ft.

For an analysis of the water, *see* pp. 286, 287.

There are three boreholes some distance from the well.

Datchet, cont.

3. Slough Waterworks. In a field on the other side of the road from the pumping station.

Made and communicated by Messrs. Isler and Co., 1919. 23 ft. of 14 in. tubes, 2½ ft. down; 72 ft. of 12 in., 1½ ft. down; water-level, 5½ ft. down.

	Thickness. Ft.	Depth. Ft.
Mould	1	—
[River Gravel] Ballast	19	20
[Reading Beds] { Mottled clay	40	—
[Reading Beds] { Clay and stones	5½	65½
[Upper] Chalk and flints	100½	166

Denham.

Ordnance Map 255, new ser. (Bucks. 48, SE., 49 SW., 53 NE., 54 NW.)
Geologic Map 7.

The Tile House, nearly 2 miles north of the village. 1851.
Communicated by W. F. Vernon.
Dug 110 ft.; the rest bored.
Water rose to nearly 85 ft. from the surface of the ground.

	Thickness. Ft.	Depth. Ft.
Yellow [? London] Clay*	22	22
[Reading Beds] { Gravel and sand, mixed ...	15	37
[Reading Beds] { Gravel sand and chalk mixed†	30	67
[Upper] Chalk	128	195

* No London Clay has been mapped here by T. R. Polwhele. Perhaps this clay may belong to the Reading Beds.
† Part of this bed may belong to the Chalk.

Dinton.

Ordnance Map 237, new ser. Geologic Map 46 SW.

Moreton (eastward of Ford). Coprolite-works on the top of the hill.
Communicated by H. Wilkinson, of Leighton.

Gault clay	about 60	{ Between 60 and 70 ft.
Limestone-rock [? Portland] with a good spring of water	?	

Mr. Wilkinson stated that at the Coprolite-works near Ford this rock could not be found, and that he bored nearly 200 ft. through clay without getting water.

Ditton Park, *see* Horton.

Edlesborough.

Ordnance Maps 220, 238, new ser. (Bucks. 33, SE., 37, NE.)
Geologic Map 46, SW.

1. Near Mill, for the supply of the village, 1863.

T. M. Smith. In "Metropolitan Board of Works. Reports on the Boring Operations at the Crossness Pumping Station." 8vo, *Lond.*, 1869, p. 20 and pl. 3. And from specimens sent by Mr. Smith.

Boring of 6 in. diameter (? decreasing downward). Lined with 72 ft. of 4¾ in. tube for 72 ft.; then with 216 ft. of 3 in.; then 13 ft. of 2 and 1¼ in.
Water-level 70 ft. down, January, 1869.

	Thickness. Ft.	Depth. Ft.
Chalk Marl (partly classed as Lower Chalk; but there is nothing here above the Chalk Marl); 50 ft. down with very small dark grains ... ... Upper Greensand (? base of Chalk Marl)	63	63
Gault. Specimen 70 ft. down, grey, sandy, calcareous clay. 143 ft. down a 3 in. bed of phosphatic nodules, a 4-in. bed 223 ft. down	205	268
Lower Greensand. Specimen from top, coarse sand with small pebbles. Specimen 18 ft. lower, finer brown sand	33	301

Edlesborough, cont.

It was expected to get water from Upper Greensand; but this was found to be so very thin that no supply could be got from it, and it was scarcely to be distinguished in passing from Chalk Marl to Gault, from which one is inclined to think that there may be no true Upper Greensand, but only the usual glauconitic bed at the base of the Chalk Marl.

2. Dagnall. S. part of parish. Cross Keys Inn.
R. Comm. Metrop. Water Supply. Appendices. 1893, p. 383.
Level of curb, 446.46 ft. above Ordnance Datum.
Depth to water, September 16 (? 1892)... 52 } 73 ft.
Depth of water ... ... 21 }
But another record, 25th March, 1896, gives the depth to water as 39 ft., and to the bottom as 67½.

3. Trial-boring, for public supply. On the green in the centre of the village, 1905.
Made and communicated by Messrs. Mayne, of Stewkley.

[Soil ?]	1		
[Chalk Marl] Chalky clay	3		30 ft. ?
[Chalk Marl] Blue clay	26 ?		

At the depth of 22 ft. there was only surface-water, which came in at 8 ft. Between 22 and 30 ft. a good supply was got, rising to 4 ft. down. Four gallons a minute being pumped the water could not be lowered to more than 20 ft. down. Bore-hole piped for 12 ft. down, to keep out surface-water.

Ellesborough.

Ordnance Map 238, new ser. (Bucks. 34, 37, 38). Geologic Maps 7 and 46 S.W.

1. Chequers Court. About 500 yards north east of Great Kimble church and about 1,500 yards north west of Chequers.

A boring made and communicated by Messrs. Le Grand and Sutcliff. 385 ft. above Ordnance Datum. Water-level 13½ ft. down.

		Thickness. Ft.	Depth. Ft.
Loamy mould		3	3
Chalk Marl. Stone-coloured clay		27	30
Upper Greensand, 12 ft.	Hard grey sand	2	—
	Light-grey loamy sand	2	—
	Dark green sand	3	—
	Grey loamy sand and bands of rock ...	5	42
Gault. 20 ft.	Blue sandy clay and bands of rock ...	19	—
	Gault	1	62

For an analysis of the water, *see* p. 287.

2. Coombe. North east corner of Chequers Court Park.
From Dr. R. L. Sherlock.
Well 90 ft., with 10 ft. of water (average): goes up to 20 ft. and down to a very little.

3. Hill End cottage (north of Coombe Hill) ? well over 600 ft. above Ordnance Datum.
Bored and communicated by Messrs. Isler and Co.
Lined with 30 ft. of six-inch tubes 175¾ ft. down.
Water-level 197 ft. down. Supply 600 gallons an hour.
Dug well (? old) ... ... 197 } 243 ft.
Chalk and flints ... ... 46 }
As the well starts in Middle Chalk presumably the flints have fallen down.

Emberton.

Geologic Map 203, new ser. (Bucks. 5, N.).

From W. W. Fisher.
Boring 35 ft., through clay into sandy beds (? Drift).
Water rises 13 ft. For an analysis, *see* p. 288.

Fawley.

Geologic Map new ser. 254 (Bucks. 51 NW.).

Home Farm, in field north west of large gravel-pit (presumably Fawley Court), 1890.

Bored and communicated by E. MARGRETT.

		Thickness. Ft.	Depth. Ft.
[River Drift]	Gravel, pebbly, subangular, hard	20	—
	Loam and gravel	6	—
	Gravel	4	—
	Loam	5	35
	Black clay	2	—
	Yellow clay	1	38
	Gravel	3	41
[Upper]	Chalk	9	50

Fenny Stratford.

Ordnance Map 220, new ser. (Bucks. 15. S.) Geologic Map 46, NW.

1. Bletchley Station (which is not in Bletchley). 1887.
About 260 ft. above Ordnance Datum.

A. J. JUKES-BROWNE. *Geol. Mag.*, 1889, dec. iii, vol. vi, pp. 356–361. Boring made by TIMMINS. Water found at the depth of 390¾ ft. and at the bottom: it was salt (for analysis, *see* p. 288) and unfit for use: so the work was abandoned and a coffee-house built on the site.

	Thickness. Ft. In.	Depth. Ft. In.
Old well [? Drift and Oxford Clay]	—	148 0
Blue limestone	8 0	156 0
Hard blue clay	9 0	165 0
Black bituminous shale, with iron-pyrites	1 0	—
Yellow clay	2 6	—
Brown clay	17 6	186 0
Blue limestone	1 0	—
Brown clay	5 0	192 0
Blue limestone (sample dark grey, with oolitic structure, echinoderm spines and shell-fragments) ...	12 0	204 0
Blue clay	8 0	212 0
Blue limestone (samples grey, shelly, and partially oolitic)	5 9	217 9
Blue clay	6 3	224 0
Blue limestone (sample from 224 ft. light-grey, crystalline, very hard, with calcite)	1 0	—
Blue clay, hard, with septaria and pyrites	36 0	261 0
Blue limestone	1 0	—
Blue clay, hard, with septaria	40 0	302 0
Blue limestone	3 6	—
Blue clay, full of fossils	4 6	310 0
Blue limestone, full of fossils	1 0	—
Blue clay, full of fossils	45 0	356 0
Hard bluish limestone, with hard calcareous ferruginous nodules at about 360 ft.	22 5	378 5
Granite rock difficult to bore through	21 7	400 0
Clay, blue, becoming brownish on exposure	1 0	401 0
Granitic rock, not so hard as the higher bed	6 2	407 2
Clay, like that above	2 10	410 0

The geologic interest of this boring lies in the "granitic rock" found in the bottom part. Prof. BONNEY says of fragments sent to him that they "are of a rock closely allied to granite," probably microgranulite. JUKES-BROWNE remarks that "there is no proof however that the whole of the thickness given to 'granitic rock' in Mr. Timmins' account of the boring consisted of the rock above described: there is indeed strong evidence for the belief that it did not," for A. C. G. CAMERON, who visited the place when the boring was going on, got samples that "are simply sandstones, without any trace of granitic fragments

Fenny Stratford, cont.

or minerals . . . such rocks as occur in the Kellaways Beds at the base of the Oxford Clay, and the only way of reconciling their existence with the recorded occurrence of granitic rock at about the same depth is to suppose that boulders and blocks of the latter rock are here imbedded in the Kellaways sandstone."

This conclusion leads to "assigning a thickness of more than fifty feet to the Kellaways Beds, which is more than usual."

The fact that the clays associated with the "granitic rock" are not baked, agrees with this conclusion.

"The occurrence of blocks of microgranulite naturally suggests the possible proximity of . . . Palæozoic land."

Prof. P. F. KENDALL, however, was led to "suspect that some beds of greater geological age than the Oxford Clay occur in the lower part of the Bletchley borehole" (Final Report R. Comm. Coal Supplies, pt. ix, p. 25), and in 1913, from evidence got from a deep boring at Calvert (*see* p. 160), Dr. A. M. DAVIES suggests a different reading of the section (*Quart. Journal Geol. Soc.*, vol. lxix, p. 333), as follows :—

Oxford Clay	192
Forest Marble	33
Lias (Charmouthian)	185

He thinks that this boring "if it did not actually touch the Palæozoic floor came extremely near to it," and he infers that this floor here consists of Charnian igneous rocks.

For analysis of the water, *see* p. 288.

2. Brewery, west of canal and south of High Street.

Communicated by Mr. G. HALDOM.

Shaft 50 ft., the rest bored, the bore-pipe about 20 ft. up the shaft.

Before the boring was made a certain amount of water was got from land-springs, and this water still comes into the shaft.

Oxford Clay, to rock [? cement-stone], from which water rose 10 ft. above the bore-pipes, and there has been a good supply since, 150 ft.

3. Saw-mills, just west of Simpson Road and north of Railway.

Communicated by Messrs. ROWLANDS.

Shaft 60 ft., the rest bored and not lined (3 in. diameter). Total depth, 99 ft.

Good supply, about 2,000 gallons a day pumped. (A note, got by Mr. CAMERON from a well-sinker, apparently referring to this well, makes the water-level 38 ft. down.)

Oxford Clay, to rock [? cement-stone], from which water rose to within 32 ft. of the surface. It has sometimes been pumped down to 4 or 5 ft. from the bottom of the well.

These two borings (2, 3) are of much interest. They have been successful, where success could hardly be expected. The source of supply would seem to be from stony layers in the Oxford Clay, the depth not being enough to reach to the base of that formation. Moreover, the two seem to have tapped separate sources, the well at the Saw-mills having its supply from a higher bed than that which yields the water at the brewery, at a slightly lower level than the saw-mills, where no water seems to have been found at the higher level. That an unlined bore in a clay should have kept open for 10 years or more is also lucky.

4. Trial-boring, near the northern side of the high road south-east from the bridge at Fenny Stratford Railway Station. 1889.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

	Thickness. Ft.	Depth. Ft.
Yellow clay	4	4
Boulder clay	13½	17½
Clay and sand	4	21½
Boulder clay, with 3 in. of rock at the middle ...	4½	26
Green sand and ironstone	22	48
Green sand	32	80
Brown sand and ironstone	11	91
Brown loam, with ironstone occasionally	42	133
Oxford Clay ?	12	145

Fenny Stratford, cont.

The following three wells (5-7) from A. C. G. Cameron's notes:

5. For temporary supply to the station, while the Bletchley boring was in progress. By the side of the Railway between Fenny Stratford and Bletchley. Gravel and gravelly clay, to water and clay, 18 ft.

6. Railway Hotel, Bletchley Station. Well 80 ft. in very hard clay. No springs.

7. Cottages between Bletchley Station and Hall (may be in either parish). Well 70 or 80 ft. in clay. No springs, but water drains in during damp weather.

Foscott.

Ordnance Map 219, new ser. (Bucks. 13, N.E.) Geologic Map 45, NE.

Noted by H. B. Woodward.
Well in Drift Gravel, 80 ft. No water.

Fulmer.

Ordnance Map 255, new ser. (Bucks. 53, N.E.). Geologic Map 7.

1. Mr. J. Kay's House.

Sunk and communicated by C. Page.

Gravel	14½	85 ft.
Sand [Reading Beds]	33¼	
Chalk	37¼	

2. Public well, close to the church.

Made and communicated by R. B. Paten.

Shaft 17 ft, the rest bored.

Clay and sand [Reading Beds] ...	52	157 ft.
Chalk with flints	105	

Halton.

Ordnance Map 238, new ser. (Bucks. 34, NW.). Geologic Map 46, SW.

Near the church, for the supply of the mansion.

About 400 ft. above Ordnance Datum.

Information, got on the spot, by A. J. Jukes-Browne, and notes from E. T. Mackrill, of Aylesbury.

Shaft, with headings at the bottom, 57 ft., the rest bored.

First water found 30 ft. down.

Well described as principally through Chalk Marl with occasional thin bands of Gault. As springs rise from the base of the Chalk Marl on the north, the beds passed through may be classed as follows:—

Chalk Marl	30	172 ft.
? Upper Greensand. Hard tough chalk ...	17	
Gault. Dark clay	125	

Another account makes the depth 177 ft.

Hambledon.

Geologic Map 254, new ser. (Bucks. 51).

1. The Schools. Dug and communicated by S. Joyce.
Three wells, 39, 42, and 47 ft. deep.
Water-level 4 ft. from the bottom.

2. At River Holme, Mill End, south of the village, a boring was made by Callas, to the depth of 100 ft., and lined with 70 ft. of 4-in. tubes.

Hanslope.

Ordnance Map 202, new ser. (Bucks. 4, SE.). Geologic Map 52, SW.

For the Newport Pagnell Rural District Council. 370 yards north-eastward along Woodend Lane, from Long Street.

400 ft. above Ordnance Datum.

Information from the Local Government Board.

Water-level at commencement of pumping 304 ft. above Ordnance Datum. at cessation of pumping 287 ft. In 51 hours water reached to within 3 ft. of original level.

Yield, as found by continuous pumping for 14 days, from 20,230 to 28,500 gallons a day.

		Thickness Ft.	In.	Depth. Ft.	In.
Mould		0	6	0	6
[? Boulder] Clay		76	6	77	0
[Great Oolite] ...	Brown rock	12	6	—	
	Black sandy clay ...	0	9	—	
	Rock (oolite)	2	9	—	
	Light-blue clay	3	0	—	
	Rock	3	0	—	
	Black clay	2	0	—	
	Rock	6	0	107	0
[?Upper Lias] ...	Light-blue clay	3	0	—	
	Black peaty clay ...	7	6	117	6

Dates of pumping and yield per day, in gallons, in 1909.

22nd and 23rd February	28,500
24th February	28,070
25th ,, ...	26,125
26th ,, ...	24,430
27th ,, ...	22,130
28th ,, ...	21,110
1st to 7th March, all	20,230

Pumping was carried on continuously for 14 days, except for a short interval each day, for measuring the rate at which water rose.

For analyses of the water, *see* p. 289.

Horton.

Ordnance Map 269, new ser. (Bucks. 56, E.). Geologic Map 7.

Ditton Park. NW. of the village.

Information, got by Sir A. Strahan, from J. Pond, Bailiff.

Water overflows into a tank 19 ft. above the ground.

Gravel	about 10	450 ft.
London Clay [must be mostly, or wholly, Reading Beds]	,, 60	
Chalk, to main spring	,, 380	

Horwood, Great.

Ordnance Map 219, new ser. Geologic Map 46, NW.

Two wells, from A. C. G. Cameron's Notes.

1. The Cottage. Half a mile NW. of Little Horwood.
Water stood 3 to 4 ft. in the well. It rises quickly after heavy rain. The well was dry once, June, 1893.
Glacial Drift { Gravel, 10 ft. / Boulder Clay. Blue clay and water.

2. Windmill, SSW. of the village.
Water stood 8 ft. in the well.

[Glacial Drift] { Boulder Clay. Stony clay	20	30 ft.
[Glacial Drift] { Sand and gravel	10	

Horwood, Little.

Ordnance Map 219, new ser. (Bucks. 19, N.) Geologic Map 46, NW.

Horwood House, W of Swanbourne Station, 1911.

Made and communicated by GEORGE C. TILLEY and Co.

Water found between 24 and 27 ft. down. Water-level (28th October, 1910) 20 ft. down. This water was shut out as it was not considered good.

H. B. WOODWARD supplied the classification of the Lower Oolites.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
[Drift]	Clay and stones	2	—
	Gravel with pieces of Chalk	2	—
	Rubble and sand	4	—
	Light-brown loam	2	—
	Sand and gravel	8	—
	Fine light-red sand and a little water	5	—
	Pea gravel and a little water	2	—
	Sharp red running sand and water	11	37
	Dark blue clay	54	—
	Light-coloured slaty clay and thin beds of rock	97	—
[Oxford Clay. 223 ft].	Rock	1	—
	Slate-coloured clay	8	—
	Rock	1	—
	Slate-coloured clay	12	—
	Dark-chocolate-coloured clay. A few shells	50	260
[Cornbrash]	Rock	3¾	263¾
[Great Oolite]	Clay	13¼	277
	Hard dark green sandstone, dry (I though this might be Kellaway's Rock, W.W.]	6	—
[Great Oolite].	Very hard rock (?limestone) and thin bed of green clay	14½	—
	Dark green sandstone (?limestone, as above)	2½	—
[Estuarine Beds and Northampton Beds].	Light-green rock	1¾	301¾
	Dark green clay	2¼	—
	Dark green sand and shells	3	—
	Gritty stone with their partings, slate-colour	11	—
	Dark sand-rock with a little water	1½	—
	Light-coloured sandy loam; cuts as rock in the solid	5½	325
[Upper Lias]	Hard rock	2	—
	Blue clay	2½	329½

For an analysis of the water, *see* p. 290.

According to A. C. G. CAMERON a wheel-well, in Grass Park passes through 14 ft. of Glacial sand and gravel. Water always plentiful.

He also notes a well at Horwood House (older than that given above) as being dug 50 ft. in Glacial sand and gravel (probably Boulder Clay in part) and bored 100 ft. in Oxford Clay, with rock (a stone-bed in the clay) at the bottom. Water stood 18 ft. in the well.

Ickford.

Geologic Map, new ser. Oxford, special sheet (Bucks. 31, SE., 32, SW.).

E. PARRY, Surveyor to the Rural District Council of Long Crendon, writes that a well was sunk near the church early in 1905, to the depth of 25 ft., in Kimmeridge Clay, and that no water was found.

According to "The Geology of the Country around Oxford," 1908, p. 127 "Wells, 37 or 38 ft. deep, obtain water from a 'stone-layer,' which, however, is not always present. It is about 15 ft. down on the eastern side of the village. Water is also obtained in shallower wells from fine gravelly beds of no great thickness, and from soakage through soil of gravelly loam."

Iver.

Ordnance Map 255, new ser. (Bucks. 53, E., 54, SW.). Geologic Map 7.

1. Delaford Park, northward of the village. 1888.
Communicated by J. R. Ravenhill, and by Messrs. Tilley.
Boring. Water-level 21 ft. down.

		Thickness. Ft.	Depth. Ft.
Made ground		3	3
[River] gravel		15	18
[London Clay, 103 ft.]	Yellow clay	4	—
	Blue clay	92	—
	[Basement-bed]. Green sand and black pebbles	7	121
[Reading Beds, 75 ft.]	Mottled clay	45	—
	Grey sand	24	—
	Black clay	6	196
Chalk and flints		50	246

2. Huntsmoor Park, eastward of the village. 1890.
Daily Chronicle, 4th April, 1890.
Made by Islers. 200 ft. in just over 4 weeks.
As soon as Chalk was reached water rose to 14 ft. above ground, and at 5 ft. the overflow was at the rate of 200,000 gallons per hour through a 4-in. bore. Water very pure.

3. Nine Borings. In the bottom of the valley of the Alder Bourne northward of the western end of Long Coppice and near the parish-boundary (the stream). To supply water to watercress-beds. 1893, 1895, 1899.
About 120 ft. above Ordnance Datum?
Made and communicated by Messrs. Le Grand and Sutcliff.

		Thickness. Ft.	Depth. Ft.
1.			
[River] gravel		12	12
[Reading Beds, 40 ft.]	Mottled clay	18	—
	Sand	19	—
	Blue sandy clay and shells	1	—
	Sand and stones	2	52
[Upper] Chalk and flints		98	150
2.			
[Alluvium] Stiff clay		2	2
[River] Gravel		8	10
[Reading Beds]	Stony clay	24	—
	Sand	15	—
	Stony clay and shells	2	—
	Stony marl	10	61
[Upper] chalk and flints		59	120
3.			
[River] Gravel [extraordinarily thick]		67	67
[Reading Beds] Stony clay		12	79
[Upper] Chalk and flints		91	170
4.			
Soil		4	4
[River] Gravel		41	45
[? Reading Beds.]	Stony and chalky clay	5	—
	Clay and stones	5	55
[Upper] Chalk and flints		107	162
5.			
[River] Gravel		25	25
[Upper Chalk. 168 ft. ?]	Chalk and flints	38	63
	Gravel [? pipe in the Chalk]	22	85
	Clay and stones [? pipe in the Chalk]	2	87
	Chalk and flints [? pipe in the Chalk]	106	193

Iver, cont.

6.	Thickness. Ft.	Depth. Ft.
[Alluvium] Bog	2	2
[River] Gravel	41	43
[? Reading Beds] Clay and stones	7	50
[Upper] Chalk and flints	133	183

In all of the above water overflowed.

No. 7 is 102 ft. deep. No. 8, 108 ft. No. 9, 120 ft.
No. 3 is the most northerly.

Ivinghoe.

Ordnance Map 238, new ser. (Bucks. 30, W.). Geologic Map 46. SW.

Brewery.
Communicated by Mr. Roberts.
Two wells in the brewery and a well in the neighbouring meadow. The former 30 ft. deep, with headings at the bottom (one 45½ ft. long, the other 24). Borings go down to 170 ft., when further work was stopped by "shifting Gault."
Water-level, when there has been no pumping, 9 ft. above the bottom of the wells.
For an analysis of the water, *see* p. 292.

Lane End (? Parish).

Geologic Map 254, new ser. (Bucks. 46, NE.)

Wycombe Court, southward of the village. 1908.
About 550 ft. above Ordnance Datum.
Made and communicated by Messrs. Duke and Ockenden.
Boring, lined with 8-in. tubes to 155 ft.
Water-level 241 ft. down. Yield tested at 1,200 gallons an hour.

		Thickness. Ft.	Depth. Ft.
	Sand and gravel	7	7
	Gravel and flints	8	15
	Marl and flints	4	19
[Upper and Middle Chalk.]	Chalk and flints	240	259
	Rock...	7	266
	Chalk and flints	184	450

The Rock may be Chalk Rock, marking the base of the Upper Chalk.
For an analysis of the water, *see* p. 292.

Langley Marish.

Ordnance Map 269, new ser. (Bucks. 56, NE.). Geologic Map 7.

1. Langley House, southward of the village.
From R. C. Trench's Note-book.
To Chalk 124 ft.

2. Langley Cottages. For the Great Western Railway Co.
85 ft. above Ordnance Datum.
Boring of 4 in. diameter.
Water-level 3 ft. down.

Soil and mould		1	
[River Drift]	Clay [Brickearth]	4	60 ft.
	Ballast [Gravel]	10	
London Clay		45	

Lee.

Ordnance Map 238, new ser. (Bucks. 38, NE.). Geologic Map 7.

Jubilee Well, from Dr. R. L. Sherlock's Notes.
Just over 600 ft. above Ordnance Datum.
About 15 ft. of water.

Clay with flints ...	50	about 275 ft.
Chalk ... ... about	225	

Lillingstone Dayrell.

Ordnance Map 202, new ser. (Bucks. 8, SE.). Geologic Map, 45 NE.

Midway between Tile House and Tilehouse Wood. SW. corner of the parish. Communicated by Messrs. Easton and Anderson, "from the somewhat insufficient data provided by the well-sinkers."
Shaft 21½ ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
Soil, etc.		7½	7½
Drift	Gravel ... ... about	8½	16
	Blue clay ... ... about	9	25
Oxfordian	Sandy clay	40	65
	Stiff clay	25	90
? Great Oolite Hard stone		18	108
[Upper Estuarine Series.]	Clay	22	130
	Black stuff	1	131
	Greenish clay	10	141
? Northampton Beds. Hard stone rock		9	150

The classification of the beds is by H. B. Woodward, who (publishing the section in 1895) notes the boring as "near Akeley," but it is just outside that parish. He says that "there is considerable difficulty in interpreting the record, owing to the absence of beds that can clearly be classed with the Cornbrash and Forest Marble or Great Oolite Clay. The 'Hard Stone' is too thick to be Cornbrash, judging from the local evidence, and the underlying clays appear too thick to be included with the Great Oolite Clay" and he thinks that the fault shown on the map northward of Akeley may extend to the boring, with the result that the Cornbrash and part of the Great Oolite is cut out, as shown in the figure with which he illustrates this explanation. (Jurassic Rocks, vol. v, pp. 47, 48, Fig. 23.)

Another version gives the following details of the upper beds:—

Soil and loam	7	46½ ft.
Sand	3	
Blue clay and rock ...	6	
Ironstone	1½	
Dry sand and gravel ...	24	
Hard blue clay ...	5	

Linford, Great.

Geologic Map 203, new ser. (Bucks. 10, W.).

H. B. Woodward has noted a well, at the Green, 30 ft. deep in blue clay, with *Belemnites* and a small *Gryphæa* (? Drift). *See also* p. 113.

Linford, Little.

Geologic Map 203, new ser. (Bucks. 10, NW.).

The Local Government Board Return of 1915, p. 246, states that J. M. Knapp supplies the parish from:—"Well in Greensand at Little Linford. The average daily quantity of water available is 1,000 gallons." The supply must come from a sand under the Oolitic limestone. Water satisfactory. For analyses, *see* p. 293.

Linslade.

Ordnance Map 220, new ser. (Bucks. 20, SE., 24. NE.). Geologic Maps 46. NW. and SW.

Two wells, from A. C. G. Cameron's notes.

1. New house (1896) on the Stoke road, eastward of the railway-tunnel.

All shaft. Water 61 ft. down.

Lower Greensand. Yellow sand, with sand-rock, 64 ft., to clay.

Linslade, cont.

2. New cottages (1896) 300 yards south-west of Leighton railway-station.

All shaft. Water 45 ft. down.

Gault.	Clay	22	48 ft.
Lower Greensand.	Sand	26	

3. For the London and North Western Railway Co. Near the southern entrance to the Linslade tunnel.

This was published in the Memoir on the Water Supply of Bedfordshire, under Leighton ; but it is not in that county.

Made and communicated by Messrs. Le Grand and Sutcliff.

About 330 ft. above Ordnance Datum.

Water-level 35 ft. down.

		Thickness. Ft.
Soil		2
[Lower Greensand, 110 ft.]	Soft red sandstone and layers of sand ...	34
	Red sand : a little water	15
	Live red sand	31½
	Coarse live sand and small pebbles	10½
	Blowing sand	8
	Sandy blue clay	3
	Blowing sand	5½
	Sand and clay	2½

4. Waterworks. For the Rural District Council. About a third of a mile NW. of Leighton Station. 1900.

Boring. Communicated by Messrs. Sands and Walker, of Nottingham.

330·5 ft. above Ordnance Datum.

Steel tubing of 13½ in. diameter, the bottom 20 ft. perforated.

Water rose to 64 ft. down when the pump was not working, and stood 7½ ft. lower during pumping.

		Thickness. Ft.	
Soil		5	
Ballast [gravel]		1	
[Lower Greensand]	White sand	? 80	150 ft.
	Sand-rock, 1 ft.		
	Fine silver-sand		
	Coarse yellow sand		
	Rock-clay	1	
	Black clay	4	
	Fine white sand	59?	

The water is wholly got from the last bed ; the clay above seems to shut off water from the higher sands.

Another account shows a shaft of about 30 ft., with a boring of 5 in. and of 3 in. diameter, at a level 317·5 ft. above Ordnance Datum.

5. Waterworks. in a field adjoining Perth House, on the southern side of the Soulbury road, NW. of Leighton Station. 1900 ?

From Messrs. Sands and Walker.

375½ ft. above Ordnance Datum.

Shaft about 30 ft., the rest bored (5 in. diameter, and then 3), lined to the bottom.

Linslade, cont.

Water-level 48½ ft. down.

		Thickness. Ft.
Soil		4
[Lower Greensand, 146 ft.]	Yellow sand	3
	Hard reddish sand	1
	Yellow sand	1½
	Hard reddish sand	1
	Yellow sand	4½
	No details (work done before Messrs. Sands and Walker were employed) [presumably all sand]	57
	Yellowish sand	37
	Vein of clay and stones	½
	Yellow sand	6
	Greenish sand	1
	Whitish sand	1
	Stone, sandy	½
	Clayey sand (with veins of grey clay)	6
	Grey sand	6
	Stones	½
	Grey sand	19½

Another account makes the depth 148 ft.

Average daily supply 32,000 gallons, from the Soulbury Road Works. For analyses, *see* p. 293.

A somewhat different account has been received from Messrs. Isler and Co., but it is doubtful to which of the above it refers.

6. For Wing Rural District Council. In field No. 46 on Ordnance Map, about 370 yards south of Leighton railway-station. 1,100 yards southward of the Linslade well (*see* p. 142). On the western side of the railway.

Information from the Local Government Board, and from Messrs. Sands and Walker.

283 ft. above Ordnance Datum.

An 11-in. bore.

Water-level 268 ft. above Ordnance Datum = 15 or 16 ft. down. When pumping 30 ft.

Yield, as found by continuous pumping for 14 days, 60,000 gallons a day; but the average daily quantity of water got is 18,000.

		Thickness. Ft. Ins.	Depth. Ft. Ins.
[? Glacial Drift]	Clay and soil	5 0	—
	Stiff clay	5 0	—
	Clay and sand	5 0	—
	Sand with a little clay	5 0	—
	Clean yellow sand	5 0	—
	Sand, gravel and clay	2 0	27 0
	Clean yellow sand	3 0	—
[Lower Greensand]	Yellow sand, with thin bands of ironstone at 40, 50 and 63 ft. ...	62 0	92 0
	Stone and black clay	0 8	—
	Clean yellow sand, with thin bands of stone at 97, 98½ ft.	7 4	100 0
	Stone	1 0	—
	Clean grey sand, with thin band of stone at 109 ft.	11 0	—
	Stone and black clay	0 9	—
	Clean grey sand, with thin band of stone and clay at 118 ft. ...	7 3	120 0

For an analysis of the water, *see* p. 294.

Long Crendon.

Ordnance Map 237, new ser. (Bucks. 32). Geologic Map 45, SE.

Old Court House, 1912.

About 340 ft. above Ordnance Datum.

From S. H. Hamer, Secretary of The National Trust.

Water-level 7 ft. down ?

Soil and loose rubble	5	19 ft.
Rubble-rock	9	
Sand	5	

Loudwater.

Ordnance Map 255, new ser. (Bucks. 47, E.) Geologic Map 7.

1. Ashdown Paper Mill. Adjoining the river about a quarter of a mile north of the railway-station. 1914.

Boring made and communicated by Messrs. Duke and Ockenden.

12-ft. of 24-in. tubes; 19-in. tubes to 75 ft.; grouting between the two.

Rest level of water 15 ft. down. Tested to 4,200 gallons an hour.

[Upper] Chalk and flints, 310 ft.

The use of another boring had been discontinued on account of getting fine sand and silt in it, which was believed to have been drawn in from the river.

2. Snakeley Paper Mills (Ford's). SE. of Railway-station.

Made and communicated by Messrs. Isler & Co.

Lined with 17⅓ ft. of 24-in. tubes from 14 ft. down.

Rest-level of water 19 ft. down.

Yield 20,000 gallons an hour.

Dug well	15	
[River] Gravel ...	12	305½ ft.
[Upper] Chalk	278½	

Maid's Moreton.

Ordnance Map 219, new ser. (Bucks. 13. E.) Geologic Map 45, NE.

1. Buckingham Waterworks. 633 yards W. of Maid's Moreton church.

? Second boring 10 ft. from centre of older one.

From the Local Government Board (and from W. W. Fisher 1901).

374 ft. above Ordnance Datum.

Lined with 8½-in. steel tubes to the depth of 110 ft.; then to bottom (301 ft.) with 7¼ in. perforated steel tubes.

Water in gravel 32 ft. down.

Water-level at beginning of test-pumping, Aug. 3, 1901, 6 p.m. 249 ft. above Ordnance Datum; at cessation of pumping, Aug. 17, 6 p.m. 246 ft. Water returned to original rest-level in 12 hours. Later (? August, 1907) the rest-level is given as 251·5 ft. above Ordnance Datum.

Yield, from existing borehole reconstructed in 1901, as found by 14 days pumping (*see* above) 216,000 gallons a day. But the supply from the two wells reaches only 60,000.

Classification by H. B. Woodward.	Thickness. Ft.	Depth. Ft.
Soil	4	4
Drift — Mixed gravel and sand	27½	—
Drift — Running sand and gravel	2½	—
Drift — Blue clay	44	78
Cornbrash. Mixed clay and rock (hard compact limestone)	10	88
Great Oolite Clay. — Yellow clay (soft limestone with clay bands)	8	—
Great Oolite Clay. — Blue clay	6	—
Great Oolite Clay. — Limestone and clay	5	107
Great Oolite — Hard yellow oolitic rock with thin layers of clay (soft limestone, water-bearing)	33	—
Great Oolite — Hard blue limestone (shelly) little water	2	142
Upper Estuarine Beds. Blue clay	15	157
Northampton Beds. Hard blue limestone (shelly) ...	6	163
Upper Lias. Blue clay	68	231
Marlstone (soft limestone, sandy and with bands of clay)	19	250
Lower Lias ? Blue clay	51	301

Maid's Moreton, cont.

2. Another boring. 1909. Within about 20 ft. of the Buckingham side of the reservoir.

Made and communicated by Messrs. Potter and Co.

Bore-tube 12 in. in diameter, with perforated tubes through the water-bearing beds.

Yield about 12,000 gallons an hour. A little very fine sand came up with the water.

		Thickness. Ft. Ins.	Depth Ft. Ins.
[Glacial Drift]	Gravel and loamy sand	20 0	—
	Gravel and flint	4 6	—
	Loamy ballast [Gravel]	7 0	—
	Loamy ballast with a little sand ...	2 6	34 0
	Blue clay (? Oxford Clay)	46 0	80 0
[? Cornbrash]	Limestone-rock	13 0	93 0
[Great Oolite Clay.]	Soft limestone and fuller's earth ...	3 0	—
	Hard rock	3 0	—
	Dark clay	8 0	107 0
[Great Oolite]	Very hard rock	7 6	—
	Hard limestone	19 6	—
	Hard and very broken rock	4 6	138 6
	Clay	2 6	141 0
	Stone	3 0	144 0
[Upper Estuarine]	Blue clay	11 0	155 0
[Northampton Beds.]	Hard Rock	3 0	—
	Hard limestone	7 6	165 6
	Clay	9 0	—
	Rock	1 6	—
	Very hard dark clay	52 0	—
[Upper Lias]	Rock	1 0	—
	Clay	1 0	—
	Rock	1 6	—
	Hard clay	2 4	233 10
	Grey rock	7 2	—
	Green sand	0 9	—
[Marlstone]	Rock	1 3	—
	Green sand	0 6	—
	Rock	5 3	248 9
[? Lower Lias]	Clay	1 3	250 0

I have followed the classification given by Woodward in the foregoing section (with the suggestion as to Oxford Clay made on a copy of this section).

Details of test-pumping from 6 p.m. on August 3rd to 6 p.m. on August 17th, 1901.

From James Smith.

Date.	Gallons pumped [in 24 hours].
August 3rd	160,747
,, 4th	177,210
,, 5th	187,200
,, 6th	,,
,, 8th	,,
,, 9th	194,220
,, 10th	,,
,, 11th–16th	205,830, in all.

Water-level on August 3rd, 6 p.m., 125 ft. down.
,, ,, 17th, 6 p.m., 128 ,,
,, ,, 18th, 6 a.m., 125 ,,

For analyses of the water from these works, *see* p. 295.

Maid's Moreton, cont.

3–12. Borings made by the Buckingham Town Council, to prove the ground, presumably with regard to a supply of water from gravel, etc.

From W. Topley's notes. 1889.

A. Just S. of parish-boundary, about 210 yards W. of road to Akeley.

Bog	1	40 ft.
Gravel and sand, with water... ...	4	
Hard clay	35	

B. Just S. and E. of parish-boundary (corner), about 250 yards W. of road to Akeley.

Mixed soil	2	29 ft.
Clay, no water	27	

C. S. of corner of parish-boundary, by ditch, about 310 yards W. of road to Akeley.

Mixed soil	4	33 ft.
Clay; water	29	

D. Close to parish-boundary, near corner, about 265 yards north-eastward of Bycell Farm, on road to Stowe.

Clay, 33 ft., no water.

E. At parish-boundary and NE. side of road to Stowe, just E. of Bycell Farm.

Gravelly soil	4	33 ft.
Clay, with stones in top part, the rest clean, no water	29	

F, a. By corner of Willowthorn Spinney, about 90 yards SE. of road to Stowe.

Mixed soil	4	19 ft.
Sand. Water 6 ft. down (382 ft. above Ordnance Datum)	15	

F. About 130 yards SE. and nearly 60 from the road. 387·8 ft. above Ordnance Datum.

Soil	1	40 ft.
Clay	37	
Sand and water, which rose 25 ft. ...	2	

G. Nearly 150 yards from the road to Stowe, about 190 yards NW. of its junction with the road to Akeley. 393·1 ft. above Ordnance Datum.

Clay	36	38 ft.
Sand and water, which rose 27 ft. ...	2	

H. On west side of road to Stowe at its junction with road to Akeley. 393 ft. above Ordnance Datum. Water-level 384 ft.

Gravel and stony soil	15	25 ft.
Clay	9	
Rock	1	

I. By west side of road to Akeley about 530 yards north of its junction with road to Stowe. 396¼ ft. above Ordnance Datum.

Soil	1	118 (given as 116) ft.
Oxford Clay	102	
? Kellaways Beds .. Dirty clay	6	
? Kellaways Beds .. Sandy clay	5	
? Cornbrash ... Rock	1½	
? Cornbrash ... Clay	1	
? Cornbrash ... Rock	1½	

J, K, and M are in the parish of Akeley, *see* p. 120.

This set of borings gives some geologic information as to a tract on which little has been published. Probably the beds are mostly Glacial Drift, except in the case of I, in which, however, one is tempted to think that some Boulder Clay may be present. This boring, however, justifies the suggestion of Prof. A. H. Green (*Geology of Banbury, &c.*, p. 35. 1864) "that patches of Oxford Clay may lie upon the hill top beneath the drift covering," instead of the whole under-Drift surface being Cornbrash, as shown on the map.

Topley thought that a considerable supply might be got from the gravel and sand, of which there seems to be a large area.

Maid's Moreton, cont.

13. The Manor House. (? Moreton House, by the church). 1909.
Made and communicated by Messrs. Duke and Ockenden.
Boring, lined with 6-in. tubes to 122 ft.
Water cut at 147 and 169 ft.
Water-level 132 ft. down.

		Thickness. Ft. In.	Depth. Ft. In.
[Glacial Drift ?] ...	Brown clay	6 0	—
	Blue clay	16 0	—
	Clay and stones	10 0	—
	Clay and gravel	9 0	—
	Gravel	46 0	—
	Brown clay and stones ...	11 0	98 0
	Clay and limestone	5 0	—
[? Great Oolite and lower beds].	Limestone	0 7	103 7
	Green and blue clay	4 5	—
	Blue clay	7 0	—
	Clay and limestone	6 0	121 0
	Blue clay	39 0	160 0
	Limestone	2 0	—
	Blue clay	5 0	—
	Limestone	3 0	170 0

It is hard to classify the beds, owing to the great amount described as clay.

Marlow, Great.

Ordnance Map 255, new ser. (Bucks. 46, SE., 47, SW., 51, NE., 52, NW.).
Geologic Map 7.

1. Water Company's Pumping Station, in large chalk-quarry in Oxford Lane, 1884.
Communicated by T. N. Watts, 1911.
171 ft. above Ordnance Datum.
Shaft 75 ft. Bored about 200 ft.
Water-level about 85 ft. down.
Starts in Chalk Rock.
According to Local Government Board Return of 1915, p. 194, the average daily quantity of water got is 169,000 gallons.
For an analysis of the water, *see* p. 297.
The Company has another pumping station at Bourne End (*see* Wooburn, p. 169).
It also supplies parts of Bisham, Chipping Wycombe Rural, Little Marlow, Medmenham, and Wooburn.

2. Wedmere Farm (Widmere, NNW. of the town).
Made and communicated by H. Chesterman of Hereford.
About 400 ft. above Ordnance Datum.
An 8-in. boring.
Abundance of water came in at the top of the clay-bed, but it ran out at the sides as fast as it came in.
10 ft. of water in the borehole

Chalk	95	
Yellow clay and flint	3	229 ft.
Chalk, the lowest 12 ft. very hard and grey	131	

Marsh Gibbon.

Ordnance Map 219, new ser. (Bucks. 21, NE., 22, NW.).
Geologic Map 45, SE.

Made and communicated by H. Heath.
Boring in Oxford Clay, to Cornbrash, 115 ft.
Water rose to the surface. Peaty in colour, but soft.
Mr. Heath stated (to R. H. Tiddeman) that the average depth of water along the anticline of Cornbrash here is 30 to 60 ft., but his well is a short way south-east of the ridge.
For analyses of the water of the public supply, *see* table, p. 297.

Marston, North.

Ordnance Map 219, new ser. (Bucks. 23, NW.) Geologic Map 46, SW.

Four wells. from A. C. G. CAMERON's notes.

1. Glebe Farm. Opposite the church.

Old well. 30 ft. deep in clay (Kimmeridge), with septaria. Marl at the bottom. Hard water.

2. Public Well (? SSW. of the church), 1876, known as the Schorne Well (Local Government Board Return of 1915), supplies also part of Little Horwood.

Shaly Kimmeridge clay, with broken shells. 20 ft. or more.

A thin layer of rock said to occur near the bottom. Water-level 15 ft. down.

On a visit, with Mr. CAMERON, I noted that it seemed astonishing how so large a supply could be got, for the pump yielded freely, despite the occurrence of a long drought. For an analysis of the water, *see* p. 297.

3. Schorne School well.

Bricked shaft in clay 30 ft. Site chosen by a water-diviner, about 1885. Water good, but not equal to that of the Selbourne spring, just below the Methodist Chapel.

4. Board School.

Information from the sinker, Mr. FALLER.

Shaft 85 ft., then bored.

[Drift]	Gravel	20		
[? Kimmeridge Clay.]	Clay	65		
	Stone	3		
	Clay	1		
	Stone	2	95½ ft.	
	Clay	1		
	Stone	2½		
	Clay	1		
	Stone	—		

Marsworth.

Ordnance Map 238, new ser. (Bucks. 29. SE.). Geologic Map 46, SW.

1. Boring at lock 38 on the Grand Junction Canal, 1855.

Particulars got by A. J. JUKES-BROWNE from an examination of the samples preserved at the office of the Canal Company at Marsworth.

		Thickness. Ft.	Depth. Ft.
Chalk	Grey chalk marl at 30 ft.	32	32
Marl.	Blue marl at 32 ft. and bluish silty marl at 35	4	36
Upper Greensand.	Micaceous and glauconitic greensand at 36 ft. and doubtless below but no other sample	?14	50
Gault 226 ft.	Clean bluish clay at 50 ft. and samples to 231	189	239
	Clay with 'coprolites' and fossils at 239 ft. ...	1	240
	Light-blue clays at 241 and 253 ft.	19	259
	Dark blue clay at 259 ft.	15	274
	Clay with pebbles of quartz and lydianite at 274 and 275 ft.	2	276
Lower Greensand 94 ft.	Coarse yellowish sand at 276 and 277 ft. ...	2	278
	Hard ferruginous sandstone at 278 ft.	1	279
	Sand and sandy clay from 279 to 293 ft. ...	?20	299
	Hard brown sandstone at 299 ft.	?12	311
	Grey sandy clay at 311½ ft.	?9	320
	Grey and yellow sands, mixed with clay ...	50	370

The "coprolite-bed" at 239 to 40 ft. is the one near the base of the Gault, the upper seam (worked at Cheddington) must have been pierced but no sample was preserved; compare boring made in the same year at Bulbourne (p. 254).

The thickness of the Upper Greensand is given as only about 6 ft. in "The Cretaceous Rocks of Britain," 1900, vol. i., p. 283. The thickness of 248 ft., assigned to the Gault on p. 279, seems wrong.

Marsworth, cont.

2. Boring at Lock 30 on the Canal. ? Near the bridge on the Cheddington road, more than a mile westward of Ivinghoe Church. Parish doubtful: may be in Cheddington.

From MS. of A. J. JUKES-BROWNE (apparently in part from specimens).

		Thickness. Ft.	Depth. Ft.
	Light-grey marly clay at 14 to 36 ft.	—	36
	Light-grey clay, hard and stiff ...	52	88
	Phosphatic nodules, with iron-pyrites	1 ?	89
	Light-grey clay	34	123
	Nodules of septaria, with calc-spar at 124 and 126 ft. (in clay ?)	3	126
	Clay, with *Ammonites rostratus* and *Belemnite* at 131 ft.	7	133
Gault ...	Phosphatic nodules and fossils (? in clay) at 134 and 135 ft. ? fallen down	2	135
	Clay, with *Inoceramus* at 139 ft. ...	8	143
	Clay. Large phosphatic nodules from 144 ft. down. ? fallen	5	148
	Grey clay, shaly at 160 ft.	12	160
	Dark blue clay	14	174
	Coarse sand, with pebbles at 174 ft. ...	4	178
Lower Greensand, 53 ft.	Soft loamy clay, like Fuller's earth at 178 ft.	? 2	180
	Yellow and grey sands	47	227

Mentmore.

Ordnance Maps 220, 238, new ser. (Bucks. 24. SE., 29, NE.). Geologic Map. 46, SW.

Waterworks, at the south-eastern edge of the Park, about 200 yards NNE. of Model Farm, 1866.

Communicated by S. C. HOMERSHAM.

Shaft 108 ft., the rest bored.

Normal water-level 70 ft. down.

Yield 200,000 gallons a day.

Gault	143	151 ft.
[Lower Greensand]. Loose sand ...	8	

Prof. A. H. GREEN noted a well here, as follows; but A. J. JUKES-BROWNE doubts so great a thickness of Gault.

[Gault.] Clay, whitish and chalky	210	211½ ft.
[Lower Greensand.] Ironstone-rock, white sand ...	1½	

Missenden, Great.

Ordnance Map 238, new ser. (Bucks. 38, S.). Geologic Map 7.

1. Pumping Station of the Rickmansworth and Uxbridge Water Co. By Balinger? Local Government Board Return of 1915, p. 210.
Boring in the Chalk, with an average daily yield of 45,000 gallons.

2. Woodlands, about a mile NNW. of the village.
Made and communicated by R. B. PATEN.
Shaft 130 ft., the rest bored.
Chalk and flints, 280 ft.
Begins in Middle Chalk, according to the map.

Missenden, Little.

Ordnance Map 255, new ser. (Bucks. 42. NE.). Geologic Map 7.

1. Holmer Court, Holmer Green, 1911.
Bored and communicated by Messrs. ISLER and Co.
About 560 ft. above Ordnance Datum.
40 ft. of 6-in. tubes 2 ft. down.
Rest-level of water 187 ft. down.
Yield 360 gallons an hour.

Clay and stones, very hard	35	352 ft.
Chalk and flints	317	

Missenden, cont.

2. Trial boring for Coal. On east side of road 3 furlongs south of Affrick's Farm, 1913.

Sir A. Strahan. Summary of Progress of the Geological Survey for 1915. Starts close below the Chalk Rock.

		Depth. Ft.
Unknown		820
Oxford Clay*	Dark clay, with fragments of *Ostrea* at	820 and 890
	Brownish clay with fragments of Oxfordian fossils ... ... at	1026
	Similar clay ... ... at	1032½
Great Oolite ..	Oolitic grains, with rounded grains of quartz became abundant. Sludge like ground-up limestone ... at	1046
	Oolitic grains less abundant, and quartz-grains more abundant downward, until the sludge became a fine-grained sand ... ... at	1065
	Fine-grained muddy sand with very small quartz-grains ... ... at	1070—1098
Doubtful † ...	Large oolitic grains and well-rounded quartz-grains ... ... at	1103½
	Muddy sands, with some oolitic grains, apparently washed down from above	1107—1197⅔
To floor of Palæozoic rocks		1200 ?
[Upper Ludlow]	Alternations of shales, limestones and some sandstone, with characteristic fossils (for details, *see* original) ...	1200—1264

* Of this it is said : "It is not improbable, however, that the clay had dropped, or been dragged by the chisel, from a higher part of the borehole."

† Of these beds "nothing can be said, except there was no red staining suggestive of Trias, and no material that could be attributed to Old Red Sandstone."

Monk's Risborough.

Ordnance Maps 237, 238, new ser. (Bucks. 37, NE.). Geologic Map 7.

Whiteleaf. Eastward of the town, and within a quarter mile of the Cross. About 500 ft. above Ordnance Datum.

Made and communicated by Messrs. Isler and Co.

90 ft. of 6-in. tubes, 108 ft. down. 75 ft. of 5-in. tubes 195 ft. down.

Water-level 118 ft. down. Copious supply.

		Thickness. Ft.	Depth. Ft.
Dug Well (? old)		—	126
[Chalk Marl ?]	Light-brown Chalk Marl	10	136
	Dark grey Chalk Marl, with occasional thin beds of rock	11	147
	Light-brown ChalkMarl, with occasional thin beds of rock	17	164
	Dark grey marl, with occasional thin beds of rock	34	198
[Gault] ...	Light-blue Gault	19	217
	Green sand	13	230
	Dark Gault, with occasional thin beds of rock	40	270

Newport Pagnell.

Geologic Map, new ser. 203 (Bucks. 10, N.).

1. Newport Pagnell Urban District Council. Well on the southern side of Lake Lane, about 1½ miles west north west of the church, 1886.

Communicated by G. A. Branford, Surveyor.

226·5 ft. above Ordnance Datum.

Originally a 7 ft. shaft to 44 ft. 7 in. down (deepened in 1893) with a 12 in. bore to 53 ft. 8 in.

Newport Pagnell, cont.

Highest water-level 39 ft. 7 in. down (1886).

Average level during a dry summer about 45½ ft. down (1886).

Water found at 17 ft. 7 in. to 21 ft. 3 in., and in abundance between 33 ft. 8 in. to 53 ft. 8 in. down.

Average daily supply 69,000 or 70,000 gallons (Local Government Board Return, 1915).

	Thickness. Ft. Ins.	Depth. Ft. Ins.
[Boulder Clay] Drift. Chalk, stones, Belemnites Gryphæa, etc.	12 8	12 8
[Great Oolite Clay]. Dark blue clay, no fossils	4 11	17 7
[Great Oolite Clay]. Hard blue limestone-rock intermixed with ironstone, very fossiliferous, Ammonites *Cerithium Portlandium Echinodermata*...	3 8	21 3
[Great Oolite Clay]. Green marl (broke into cubes on exposure)	1 3	22 6
[Great Oolite Clay]. Dark blue clay, no fossils	10 2	32 8
[Great Oolite Limestone.] Fissured limestone intermixed with ironstone, gradually getting more into a yellow slab-stone in horizontal beds about 15 in. thick. Not very fossiliferous; Ammonites	21 0	53 8
To clay [?Upper Estuarine Series]		

Abundance of water 44 or 45 ft. down. For an analysis, *see* p. 298. Lathbury is supplied from this source.

2. Test-boring for Newport Pagnell Urban District Council. In field 452, about 2 miles SSE. of church. 1914.

Communicated by G. A. Branford, Surveyor (with specimens).

Water level 9½ ft. down (when 72¾ ft. deep). Water found 51 to 52 ft. down and 59½ ft. down.

		Thickness. Ft. Ins.	Depth. Ft. Ins.
Mould ...	... ...	1 4	1 4
	Marl	3 0	4 4
	Light-brownish clay	5 2	9 6
	Light-grey clay	15 6	25 0
? Oxford Clay.	Light-grey clay and chalk-stones ...	1 0	26 0
	Limestone-rock	2 10	28 10
	Dark blue (grey) clay	9 9	38 7
	Grey calcareous clay intermixed with chalk-stones	2 0	40 7
	Limestone-rock	1 6	42 1
	Black (dark grey) clay	5 0	47 1
	Hard rock	4 3	51 4
	Flakey clay, grey and calcareous ...	0 8	52 0
? Great Oolite Clay, etc.	Hard rock	1 0	53 0
	Crumbling grey calcareous clay ...	5 6	58 6
	Hard rock. More water	3 6	62 0
	Green clay, calcareous	7 0	69 0
	Light-coloured chalky clay	3 9	72 9
	Clay	7 0	79 9
	Rock	2 0	81 9
	Light-coloured clay, with 3 in. of rock at the bottom	8 3	90 0
Doubtful.	Darker grey clay	10 0	100 0
	Lighter grey clay	8 6	108 6
	Light-coloured clay	2 6	111 0
	Light-coloured clay, calcareous ...	2 0	113 0
	Light-coloured clay	3 6	116 6

Newport Pagnell Rural District.

Dr. W. W. E. Fletcher. Report to the Local Government Board, new ser. No. 72. 1912.

Great Linford and *Weston Underwood* "are supplied with water pumped by windmills from wells," but later information credits these supplies to springs (*see* pp. 113, 114).

Newport Pagnell Rural District, cont.

New Bradwell is partly supplied by the London and North Western Railway Co., from two wells in the Wolverton and Stony Stratford Rural District.

In most of the parishes of the district water is got from wells, "some as much as 60 ft. deep; and the distances from the ground surface to the water levels vary greatly. Almost universally . . . these wells are merely surface wells in the sense that they form reservoirs for the collection of subsoil water; and, so far as was observed, all of them are dry-steined with local stone or brick. In some instances subsoil water was visible, freely percolating into the wells a few feet below the ground level, and running down their sides. Usually the tops of the wells are insufficiently protected. Very many of these wells are so situated that escape from contamination, if not from gross pollution, is almost impossible. The large village of Olney is entirely supplied from wells of the kind described." Cold Brayfield, Emberton, and Ravenstone are also noticed as offending in various ways. Astwood "is very largely dependent upon a small pond, in a field, which is said to be fed by springs. At Moulsoe there are two public wells, one is seven yards distant from the churchyard, which is on a higher level . . . and the other is close to the wall of an unpaved stock-yard, which was in a filthy condition when it was visited. . . . Loughton has an ample supply of water, it is said, from a public well, but it involves carriage by hand."

Newton Longville.

Ordnance Map 220, new ser. (Bucks. 20 NW.). Geologic Map 46 NW.
1. Rectory.

J. Farey, in P. Thompson's Collections for a Topographical Account of Boston, 1820, pp. 297, 298. Repeated in his History and Antiquities of Boston, 1856, p. 670.

A most interesting account of an old well, continued to a considerable depth, on the advice of the Father of British Geology. "Early in the spring of 1802, when my friend Mr. Bevan the engineer, and myself, were receiving practical instructions from Mr. William Smith relative to his discoveries on the stratification . . . we accidentally met with the Reverend Mr. Le Mesurier, rector of Newton-Longville, who related his having undertook to sink a well, at his parsonage house . . . but finding clay only at the depth of more than 100 ft., was about to abandon the design; Mr. Smith, on looking into his map of the strata, pointed out to us, that Newton-Longville stood upon some part of the clunch-clay strata, and that the Bedford lime stone [Gt. Oolite] appeared in the Ouse river below Buckingham, distant about 8 miles . . . and he assured Mr. L. that if he would but persevere, to which no serious obstacles would present themselves, because all his sinkings would be in dry clay, he would certainly reach this lime stone, and have plenty of good water rising very near to the surface."

The sinking was accordingly continued, with the following result, boring being resorted to at the depth of 243 ft., below which unfortunately the measurements were lost.

[Boulder Clay]. Alluvial clay, with chalk and flints, 80 ft.		
[Oxford] Clay, 155 ft.		
[Great Oolite]	Limestone: a little water, 8 ft.	
	Blue clay, for some way.	
	Limestone: good yield of water, rising to the surface.	

The Rev. A. Matheson (rector when this was written), says that the well is still used, but the water does not rise to the surface. The well is in the older (back) part, now the scullery, of the rectory, and has a strong cover, which is kept locked. The water is lifted by means of a large wheel. A supplementary supply is got from gravel, in a field near by.

2. For Public supply. Three Wells.

From the Local Government Board.

Two of them are at Lower End and 8 ft. deep. The other, at Drayton Road is 14½ ft. deep. All are of 3½ ft. diameter, and lined or steined to the bottom. The Drayton Road supply is said to come from a gravel-vein in Oxford Clay.

Oakley.

Geologic Map, new ser. Oxford, special sheet. (Bucks, 26, E., 31, NE., 32, NW.)

1. According to T. I. Pocock (The Geology of the Country around Oxford, 1908, p. 128). "Wells mostly up to 20 ft. deep in main part of village. No water in well at Oakley Wood Farm. North of Foresters' Arms, Oakley Common, there is a well that is said never to fail."

"Near Oakley the wells probably derive supplies from the cherty rock in the Lower Corallian at the base of the Ampthill Clay."

For an analysis of an Oakley water, *see* p. 299.

2, 3. From information on the spot.

2. Little London Farm, about 400 yards eastward of St. Mary's Church. About 40 ft. of water. Good supply.

3. Manor Farm, about 100 yards westward of the church.
Well on the lawn. About 30 ft. to water, of which there was plenty.
These two wells either get their water from a permeable bed in the Ampthill Clay, or else from the underlying Calcareous Grit. They have been noticed by T. I. Pocock, in the Memoir quoted.

4. New farm on nothern side of road over 1½ miles SE. from the church.
From R. H. Tiddeman's Notes.
Well 26 ft. deep, in blue clay (Ampthill Clay?) with *Gryphæa dilatata* and *Exogyra nana*.

5. Sebastopol Farm, nearly 1½ miles a little S. of SE. from the church, and near 1x hill. 1905?
From E. Parry, Surveyor to the Rural District Council of Long Crendon, and from notes taken on the spot.
Well (south of the farm-buildings) 3½ ft. in diameter, 14 ft. deep, from ground-surface.
Water-level about 3 ft. down=2 ft. below ground. 20th May, 1905.
Time taken to pump out 8 ft. of water 2 hours. When that level (10 ft. below the ground) was reached, it took over an hour to lower the water 6 in. more: The pump then got out of order, and in half an hour the water rose 2 ft. It was calculated that the water was then coming into the well at the rate of 300 gallons an hour. Next morning the water had reached its original level.
The site being in the midst of a tract of Ampthill Clay, presumably some permeable bed therein had been struck.

Olney.

Geologic Map 203, new ser. (Bucks, 2, S., 5, N.)

Nos. 1–3 are a selection from A. C. G. Cameron's Notes. Nos. 4, 5 are also from his Notes, but published in the Jurassic Rocks of Britain, vol. iv, 1894, p. 394, the classification by H. B. Woodward.

1. Brewery. Three wells Two failures. The third as follows. 1889. Yield about 30 barrels (of 36 gallons) an hour.
River gravel loam and sand, 30 ft.

2. Near the mill, by the church.
Dug 25 ft. and bored 20 in blue clay, and a little chalk stone. No water.

3. On Weston Underwood road, 150 yards W. of Market Square.
81 ft. in clay, which rested on rock.
Water-level 65 ft. down.

4. Half a mile north of the railway-station. 1891.

		Thickness. Ft.	In.	
Great Oolite limestone, with *Modiola imbricata* and *Rhynchonella concinna*		18	0	
Upper Estuarine Series.	Grey clay	10	0	45 ft. 2 in.
	Limestone	2	0	
	Black clay	10	0	
	Black shelly and carbonaceous clay, with lignite at top.	5	2	

Olney, cont.

5. Olney Court.

Great Oolite limestone, 20 ft.

Clay (Upper Estuarine Series and Upper Lias). 100 ft.

H. B. Woodward says, in "Jurassic Rocks of Britain," vol. iv, p. 394 (1894) "Wells on the flats between the market-place at Olney and the river are from 60 to 80 feet deep. It is to be presumed that the Marlstone must be reached; in this case the Upper Lias clay would be of irregular thickness, being unconformably overlaid by the Upper Estuarine Series."

Beeby Thompson has remarked that "The greater part of the town of Olney is supplied with water by shallow wells in the Ouse Valley gravel, but in the southern part of the town, between the Market Place and the river, and southwestward, on the road to Weston Underwood, the wells are from 60 to 80 ft. deep in Lias Clay." He adds that not many yards eastward of a disused brickyard, on the southern side of the road at the south-eastern end of Olney, a well made for some cottages was said to be in blue clay to the depth of 80 ft., water coming from a black rock 2 ft. thick (? near the bottom) and rising 50 ft. *Geol. Mag.* 1907, dec. v, vol. iv, p. 27.

Oving.

Ordnance Map 219, new ser. (Bucks. 23, SE.) Geologic Map 46, S.W.

New building site.

Communicated by W. W. Fisher.

		Thickness. Ft.	Ins.	
	Loam	2	6	
	Rock	4	6	
	Sandy loam	1	0	
	Rock	1	6	
[Portland Beds,	Loam	2	6	26 ft.
26 ft. 10 in.]	Rock	1	6	10 in.
	Rubble-rock	1	6	
	Rock, with water	4	4	
	Loam	1	6	
	Rubble-rock to black clay	6	0	

For an analysis of the water, *see* p. 309.

Padbury.

Ordnance Map 219, new ser. (Bucks. 18, NE.) Geologic Map 45, NE.

From A. C. G. Cameron's Notes.

1. In second field south of Lower Way

[Glacial Drift] { Boulder clay ... 6 / Gravel and sand ... 25 } 31 ft.

Water hard and rather ferruginous.

2. Ivy Cottage. Plentiful supply at 30 ft.

3. For public supply. By the side of London Road at top end of village. 1886.

Information from J. B. Hill, Local Government Board.

336·46 ft. above Ordnance Datum.

Well of 7 ft. diameter, 22 ft. deep. Drift?

Rest water-level 7 ft. down. Average quantity of water available daily 3,500 gallons.

Penn.

Ordnance Map 255, new ser. (Bucks. 42, SE., 47, NE.) Geologic Map 7.

1. Ashwell House. About a quarter-mile south-westward of St. Margaret's Church, Tylers Green. 1913.

Made and communicated by Messrs. R. Richards and Co. with some notes from Messrs. J. T. Cunnington and Co.

540 ft. above sea-level.

Hole dug for a few feet, the rest a boring of 5 in. diameter.

Chalk very dry until 275 ft. down, when there was a little moisture. A little water at 344 and 350 ft. Test-pumping, when a depth of 357 ft. was reached, showed very little water (pumped out in under half an hour). A little more water at 409 ft. Second test when a depth of 442 ft. was reached: pump ran 55 minutes full stroke, from a depth of 392 ft.: approximate quantity 254 gallons

Penn, cont.

(an hour): Water-level 280 ft. down. Supply (April, 1914) about 200 gallons an hour.

June water-level (1914) 270 ft. down; October level 275 ft.; December level 290 ft. Yield 180 gallons an hour.

		Thickness. Ft.	Depth. Ft.
	Hard chalk	30	30
	Chalk	47	77
	Chalk and flints	43	120
	Harder chalk and flints	38	158
	Chalk and flints	63	221
	Hard chalk chalk marl and flints ...	6	227
	Hard marl and flints...	19	246
	Chalk	29	275
[? Upper Chalk ? all.]	Very hard chalk	30	305
	Hard and soft chalk	5	310
	Hard chalk	8	318
	Hard and soft chalk	10	328
	Soft chalk	22	350
	Hard and soft chalk	7	357
	Chalk and flints	26	383
	Hard chalk	8	391
	Chalk and flints	9	400
[Middle Chalk.]	Hard chalk	19	419
	Hard grey chalk	4	423
	Very hard grey chalk	6	429
	Hard springy chalk	13	442

2. Rayners. About a quarter of a mile SE. of St. Margaret's Church, Tylers Green.

Information from W. VAUX GRAHAM. Section from note in Geological Survey Office.

About 547 ft. above Ordnance Datum.

Well, of 5 ft. diameter, 313 ft.

The bottom of the well is therefore 234 ft. above Ordnance Datum.

	Thickness. Ft.	Depth. Ft.
Upper Chalk	100	100
Middle Chalk. 10 in. of a reddish colour	200	300
Hard white chalk	10	310
Soft clean chalk. No flints ...	47	357

The Upper Chalk must reach to a much greater depth than is here given, perhaps to the bottom. *See* preceding section.

The water-levels at various dates were as follows:—

Years.	Levels, in feet above Ordnance Datum.				Rainfall, in inches.
1902	... ...	... ...	...	...	20·58
1903	July 1st ... 259·5	... December 28th	264·5	...	39·78
1904	July 11th ... 282· (highest)	... December 27th	273·5	...	22·86
1905	July 7th ... 267·	... ...	...	...	20·75
1906	July 14th ... 261·75	... December 21st	257·25	...	27·27
1907	April 2nd ... 257· (lowest)	... July 18th ...	262·	...	29·15
1908	January 21st ... 261·	... June 22nd and September 26th	274·25	...	28·38
1909	April 7th ... 263·16	... December 24th	262·	...	29·7
1910	June 29th ... 274·58	... December 23rd	269·41	...	31·76
1911	June 24th ... 274·5	... December 27th	264·33	...	25·18
1912	June 21st ... 278·83	... December 24th	269·25	...	37·05
1913	April 8th ... 280·5	... December 22nd	268·41	...	27·72
1914	June 22nd ... 269·16	... December 21st	263·5	...	32·77
1915	May 1st ... 276·92	... ...	...	...	...

The extreme variation recorded is therefore 25 ft.

Rainfall of 1902–1910 taken from High Wycombe gauge.

Rainfall of 1911–1914 (? 5) taken from Rayner's gauge, Penn.

Pounden.

Ordnance Map 219, new ser. (Bucks, 17, SE., 21, NE., 22, NW.) Geologic Map 45, SE.

1. Marsh Gibbon Railway Station.

A. C. G. Cameron notes that the well was sunk 50 ft. and then bored 40 in clay. There was a little water (5 or 6 ft.), which smelt.

2. Pounden Hill. About 50 yards south of the road, at the highest part of the hill, south-westward of hamlet. 1908?

Made and communicated by Messrs. Cheeld and Co. of Chesham.

Highest water-level 115 ft. down. Reduced 10 ft. by pumping 900 gallons an hour.

Classification by H. B. Woodward.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
Boulder Clay	Sandy stony clay	6	
	Clay and flint...	5	12
Oxford Clay	Slate clay	21	
	Reddish clayey sand and stones ...	3	
	Clay, with trace like coal at 42 feet	47½	
	Pyrites	½	
	Very dry clay	48	
	Septaria	¾	
	Sandy clay	25¾	158¼
Cornbrash and Forest Marble	Rock with six clay-partings ...	22¼	180¾
	Clay	2	182¾
Great Oolite.	Very hard, with two clay-partings, Rock, etc.	49½	232¼

The *depths* from 83½ to 158½, are given as a foot more, and the total as 209, in another account (from W. W. Fisher) which differs slightly in some details.

For an analysis of the water, *see* p. 299.

This is the well referred to in the Local Government Board Return of 1915, p. 246, from which J. P. Heywood-Lonsdale supplies the parish; but it is described merely as a well in Oxford Clay. The average daily quantity of water got is 9,000 gallons and more could be got.

Preston Bissett.

Ordnance Map 219, new ser. (Bucks, 18, N.W.) Geologic Map 45, NE.

1. For the public supply. In pasture-land near the Gawcott road (? near church, 1904).

Information from J. B. Hill, Local Government Board.

321·96 ft. above Ordnance Datum.

Well of 3 ft. diameter, 6 ft. deep. ? Drift.

Rest water-level 2 ft. down. Average quantity of water available daily, 3,000 gallons.

2. In pasture-land about 150 yards from Cowley Farm buildings, southward of the village. For the supply of Twyford. 1901.

Information from J. B. Hill, Local Government Board.

Three wells of 5 ft. diameter. (According to Dr. P. L. Benson in a large pocket of sand and gravel (on Oxford Clay).

No. 1. 327·71 ft. above Ordnance Datum. 9½ ft. deep. Rest water-level 4¾ ft. down.

No. 2. 328·65 ft. above Ordnance Datum. 7½ ft. deep. Rest water-level 2 ft. down.

No. 3. 330·05 ft. above Ordnance Datum. 8 ft. deep. Rest water-level 4 ft. down.

Average quantity of water available daily 7,000 gallons.

For analyses of the water, *see* pp. 271, 282.

Risborough, *see* Monk's.

Seer Green.

Ordnance Map 255, new ser. (Bucks. 48, NW.) Geologic Map 7.

(Between Beaconsfield and Chalfont St. Giles.)

Public well, at the meeting of the roads, south of the church.

According to J. S. New, Medical Officer of the Amersham Rural District Council, 130 ft. deep, in Chalk, and has a good reputation as it has never been dry. There are 4 other wells near, each over 100 ft. deep, and hard water is got from all.

Shenley Church End.

Ordnance Map 220, new ser. (Bucks. 14, NE.). Geologic Map 46, NW.

1. Shenley Park House (? Shenley Ho. of Map). 1904.

Bored and communicated by Messrs. Le Grand and Sutcliff.

Classification by H. B. Woodward.

The only water got was immediately below the well, from 47 to 62 ft.; but it was so salt and contained so much magnesia that it was unfit for drinking purposes.

		Thickness. Ft.	Depth. Ft.
Drift and Oxford Clay	Dug well (old ?)	—	47
	Rotten clay and moisture	15	62
	Blue clay	43	105
Cornbrash ...	Rock, with little water	4	—
	Rock and thin bands of clay ...	1	—
	Very hard rock	1	—
	,, ,, with a 4-inch band of clay	2	113
Great Oolite Clay.	Blue clay	2	—
	Blue clay and soft rock	3	—
	Blue clay	6	—
	Very hard rock	1½	—
	Blue clay	1½	127
Great Oolite Limestone.	Hard rock	2½	—
	,, and thin clay-partings ...	13	—
	Hard and soft rock and bands of clay	4	146½
Upper Estuarine Series.	Clay and lignite	5½	—
	Blue clay	14	—
	Hard rock and fossils. Thin band of clay at 170 ft.	8	174
	Blue clay and shells (*Avicula*, *Rhynchonella* near to *concinna*) ...	5	—
	Very hard rock	1	—
	Blue clay	4	184
Northampton Sand.	Very hard rock	2½	—
	Loamy sand	11½	198

2. The Rectory. 1909 ?

From W. W. Fisher.

Sunk 60 ft. through dark black very hard clay, which had to be picked out lump by lump; contained lumps of chalk and a few larger stones. At 47 ft. down sand and water met with. Boulder Clay.

For an analysis of the water, *see* p. 300.

Slapton.

Ordnance Map 220, new ser. (Bucks. 24, SE.). Geologic Map 46, SW.

Slapton Lock. Grand Junction Canal. 1855.

A. J. Jukes-Browne. Cretaceous Rocks, vol. i, p. 279. And from specimens examined by him.

		Thickness. Ft.	
Gault ...	Blue clay, several samples	61	86 ft.
	Coprolites, with many fossils ...	1	
	Clay, with *Inoceramus* shells at 66 ft. down	10	
Lower Greensand.	Yellow sands	14	

Slough.

Ordnance Map 269, new ser. (Bucks. 56. NW.). Geologic Map 7.

1. Eton Union.

From the Note-books of T. R. Polwhele and R. C. Trench.

		Thickness. Ft.	Depth. Ft.
Sunk (the rest bored) [? gravel, &c., and partly London Clay]		28	28
Loamy [London] Clay		24	52
[Reading Beds, 55 ft.]	Sand	2	—
	Clay	1	—
	Sand	14	—
	Clay	4	—
	White sand	5	—
	Variously coloured clay	22	—
	Marl and rock	7	107
[Upper Chalk] Flints and chalk		24	131

2. Horlick's Malted Milk Factory. Just N. of railway at the western junction of main line and Windsor branch. 1909.

100 ft. above Ordnance Datum.

Made and communicated by Messrs. Isler and Co.

Lined with 20-in. tubes for 20-ft., with 18-in. tubes for 90 ft. (from surface) and with 8½-in. tubes to 782 ft. (from surface).

Water overflowed at the rate of 100,000 gallons an hour.

		Thickness. Ft. In.	Depth. Ft. In.
Soil		6 6	6 6
[River Drift] Sands and gravel		18 0	24 6
[Reading Beds, 54 ft.]	Running sand, with brown mottled clay at 44½ to 45 ft.	32 6	57 0
	Blue clay	7 0	64 0
	Red mottled clay	8 0	72 0
	Yellow mottled clay	2 0	74 0
	Yellow clay and flints	4 6	78 6
[Upper] Chalk and flints		463 3	541 9
[Middle] Hard Chalk		154 9	696 6
[Lower Chalk, 139½ ft.]	Grey chalk	96 0	792 6
	Green sandy chalk	6 0	798 6
	Grey chalk	37 6	836 0
[Upper Greensand] Grey sandy chalk, with glauconite		19 4	855 4
[Gault] Hard blue clay		166 2	1021 6
Lower Greensand		13 0	1034 6

The total thickness of the Chalk here, 757½ ft., is 32½ ft. more than in the Winkfield boring (Berks.). Perhaps too great a thickness has been given to the Upper Chalk.

Another account makes the River Drift 18½, the Lower Greensand 15, and the total 1,037 ft.

3. Railway Station.

From Sir J. Prestwich's notes.

		Thickness. Ft.	Depth. Ft.
Gravel		10	10
[London Clay.]	Brown earth	7	—
	Black earth	3	—
	Red [? brown] clay	27	47

[This well must have been sunk at a spot where the brick-earth had been worked from off the gravel, and must go through the London Clay.]

Information from the Railway Co., which may refer to this well, gives the site as in the engine-shed, the height as 92½ ft. above Ordnance Datum, and the water-level as 84¾ ft. above Ordnance Datum.

Slough, cont.

4. Royal Nursery. 1823 ?
From R. C. TRENCH'S Note-book.

		Thickness. Ft.	Depth. Ft.
[Valley Drift, 27 ft.]	Loam [brick-earth]	6	—
	Gravel	21	27
[London Clay, 31 ft.]	Clay, various veins	3	—
	Yellow clay	28	58
[Reading Beds, 36 ft.]	Sand	6	—
	Blue clay	20	—
	Black clay	7	—
	Marl	3	94
[Upper Chalk. 17½ ft.]	Chalk	15	—
	Rock [? flint]	½	—
	Chalk	2	111½

5. Upton Park.
From R. C. TRENCH'S Note-book.

		Thickness. Ft.	Depth. Ft.
Gravel, &c., and Clay [? London Clay] ...		65	65
[Reading Beds, 73¼ (? 37¼) ft.]	Sand	40 [? 4]	—
	Mottled clays	10	—
	Sand	3	—
	Blue clay	3	—
	Blue and brown clay ...	15	—
	Black clay	2¼	102¼ [? 138¼]
[Chalk], 68 ft.	White marl and flints ...	5	—
	Chalk	63	170¼ [? 206½]

In MR. TRENCH'S note the depth to the Chalk and the total depth are respectively made 102¼ and 170¼ ft. I expect that the difference has been caused by the upper bed of sand having been given as 40 ft. instead of 4.
There are three wells here, all about the same.

6. Waterworks Company. 1869.
Communicated by E. O. SECKER.
Shaft 117 ft., with a heading in the Chalk, the rest bored (25 in.).
Water rose to a height of 7 ft. below the ground. ? Yield 40,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Top soil		1½	1½
[Valley Drift, 27½ ft.]	Brick-earth	3	—
	Gravel, with sand	24½	29
[London Clay, 20½ ft.]	Red clay	2	—
	Yellow clay	4½	—
	Blue sandy clay, very hard (much water at 48 ft.)	14	49½
[Reading Beds.]	Sand and water ... ... about	17 ?	—
	Blue and red sandy clay ... ,,	15 ?	—
	Mixed clay and sand of various colours	9 ?	90 ?
Chalk (with flints and water at 91 ft.), 27 ft. ...			
Bored deeper (in 1876)		496	586

Supplies also parts of Datchet, Farnham Royal, Horton, Langley Marish, Stoke Poges and Wexham, as well as of Hanwell, in Middlesex. Average daily quantity supplied (? from Datchet) 750,000 gallons. (From L. G. B. Return of 1915.) See also *Datchet*.

7. Slough Motor Transport Depot. This covers a large tract, largely in the parish of Burnham.
W. H. BOOTH. *Proc. Geol. Assoc.*, vol. xxxi, pt. 3, 1920, pp. 134, 138, 139.
"Temporary supplies for building were drawn from the gravel which was generally but poorly water bearing, but at one place near the middle of the site the gravel is very clean and freely water bearing and has yielded copious supplies of clean but hard water. . . . On test, the pump showed a delivery of about 28,000 gallons per hour."

Slough, cont.

"The water is hard and not suitable for permanent use in boilers. . . Tests at various points showed that only about 6 gallons per minute could be got from a 2-inch driven well (in the gravel), whereas . . . a little north (about 500 ft.) of the Middle Road Bridge the flow yielded by a pulsometer was nearly 30,000 gallons per hour and the bottom of the sump looked like a swirling river."

This supply has been continued, awaiting the completion of the deep bore (*see* Addenda). It is a highly successful supply from gravel. The particular site was found accidentally, in excavating for a sewer, at the depth of 17 ft.

For an analysis of the water, *see* p. 301.

? Soulbury.

Ordnance Map 220, new ser. (Bucks. 20, S.) Geologic Maps 46, NW. and SW.

Two wells from A. C. G. CAMERON's notes.

1. Linslade Rural District Council. Trial for waterworks, on the road to Leighton 1½ miles NW. of the railway-station.
   Shaft 45 ft., 1896; the rest bored, 1897.
   Water-level 53 ft. down.
   Lower Greensand. Sand and sand-rock 75 ft.
2. Mill Bush House, on the road to Leighton, a mile from the railway-station.
   Old well (brick). Chalky clay and hard black clay 180
   Bore, in hard black clay ... ... 70 } 250 ft.

The old shaft was deepened 10 ft. after the boring was made and two headings, of 18 and 5 ft. driven in the hard black clay, the fossils from which E. T. NEWTON thinks to be most likely of Kimmeridgian age.

Steeple Claydon.

Ordnance Map 219, new ser. (Bucks. 18, S.) Geologic Map 45, NE.

1. Railway Station.
   A. C. G. CAMERON notes that a well here was sunk 20 ft. and bored 70, passing through 90 ft. of blue clay, with hard rock (? Kellaways) at the bottom. Water from this stood 4 ft. in the well.
2. For public supply. In pasture-land about 100 yards from the Padbury road. Taken over in 1902.
   Information from J. B. HILL, Local Government Board.
   Three wells of 5½ ft. diameter (? at rear of Post Office). All in Drift.
   Average quantity of water available daily 6,500 gallons.
   (*a*) 339·03 ft. above Ordnance Datum. 16¾ ft. deep. Rest water-level 6 ft. down.
   (*b*) 332·71 ft. above Ordnance Datum. 17½ ft. deep. Rest water-level 5½ ft. down.
   (*c*) 327·68 ft. above Ordnance Datum. 9¼ ft. deep. Rest water-level 3 ft. down.

For analyses of the water, *see* table, p. 282.

3. Trial for coal. By Calvert Station, Great Central Railway. Eastern Boring (for Western, *see* Charndon). About 370 yards east of the other. 1912. About 290 ft. above Ordnance Datum.

DR. A. M. DAVIES and J. PRINGLE, *Quart. Journ. Geol. Soc.* 1913, vol. lxix, pp. 308–326, to which paper the reader is referred, for voluminous details. Cores of 18 in. diameter at first.

		Thickness. Ft.	Depth. Ft.
Soil		4	4
Oxford Clay.	Dark blue and grey, with occasional nodules. At base tough brownish shelly clay ...	93¾	97¼
Forest Marble 38¾ ft.	Bluish-grey and grey limestones, partly earthy, partly oolitic, partly shelly, with bluish-green clay at 108½ to 108¾	22	119¾
	Grey marly clays passing down into brown and greenish, with a bed of sandstone and a band of limestone. Lignite plentiful	16¼	136

Steeple Claydon, cont.

		Thickness. Ft.	Depth. Ft.
Great Oolite Series, 59½ ft.	Limestones, partly marly, partly shelly	12	148
	Grey marl and marly clay with shells	3	151
	Grey limestone	5	156
	Dark grey marl, six in., and then no core seen; beds described as soft dark grey sandy shales	25¾	181¾
	Limestones, grey, with marly band at 186¾ to 187¼	6½	188¼
	Grey marly clay, very fossiliferous, with thin band of limestone	2	190¼
	Grey limestone, with 3 in. of dark grey marl. Oyster-bed near top, thinly bedded and with lignite at bottom	5¼	195½
[Inferior Oolite].	Chipping Norton Limestone. Yellowish oolitic, partly sandy	7½	203
[Middle and Lower Lias]	Shales, with sand at 211 to 214, with limestone at 354 to 356½ and 438 to 440½, 3 ft. of clay at bottom. Many fossils	240½	443½
[Cambrian].	Lower Tremadoc. Shineton Shales, greenish-grey, red and grey, with many fossils, and dipping at a high angle (from 40 deg. to nearly vertical)	954½	1398

The geologic interest of this boring lies chiefly in two points. Firstly, in the absence of beds throughout the main divisions: thus the authors mark non-sequences (that is where the sequence of beds is incomplete, though there is no physical sign of unconformity, the planes of bedding being practically parallel), at the bases of the Oxford Clay, of the Forest Marble, of the Great Oolite and of the Inferior Oolite; whilst at the base of the Lias there is a great unconformity. Secondly, in the occurrence of old rocks nearer the surface than they have ever been recorded before in the home-counties, and in the fact that these old rocks are lower in the Geologic series, as proved by their fossils, than those found underground in various deep borings in the neighbouring counties of Herts. and Middlesex. Here too, for the first time, igneous rocks have been found, sills of olivine-basalt occurring at 570 to 572 ft. and at 606 to 608. Their effect on the sedimentary beds is slight. Allowing for the high dip the true thickness of these old shales is about 480 ft.

Stewkley.

Ordnance Map 220, new ser. (Bucks. 20, SW., 24, NW.) Geologic Maps 46, NW. and SW.

1. The following particulars were got by Prof. A. H. Green from Mr. Mayne, well-sinker, at that place:—

Gravel	8 to 10 ft.	
Clay	50	,,
Blue earthy limestone, with calc-spar	1½	,,
Clay	30	,,
Limestone, as above, with water	1	,,

2. Warren Farm. South of South End.
From A. C. G. Cameron's notes.

[Portland Beds.]	Limestone, part rubbly	2 to 4 ft.	
	Sand	9 to 12	,,
	Nodular limestone	2	,,

Stoke Mandeville.

Ordnance Map 238, new ser. (Bucks. 33, E.) Geologic Map 46, SW.

Elm-tree Farm. 1½ miles SSE. of Aylesbury Church.
Communicated by Mr. Crouch of Walton, Aylesbury.

[Gault]	Blue clay	40	55 ft.
	Hard rock	3	
	Dark blue clay, to sand with water	12	

Stokenchurch.

Geologic Map 254, new ser. (Bucks. 41, W.)

Public well. On the main road, close to the King's Arms. In a brick building with an inscription giving the date and depth (1871 and 360 ft).

? 730–740 ft. above Ordnance Datum.

About 5 ft. of water in the well; but this varies, and a few years ago the well was deepened 5 ft. The water is drawn by means of a double handed-windlass, with two large buckets, and it takes about seven minutes to draw up a bucket full of water.

Lined with brick to the depth of 36 ft.

Clay [Clay-with-flints] at the top and then chalk and rock-chalk. [It must reach down into Middle Chalk].

This is an interesting example of a village-supply of the old sort. It is perhaps the highest public supply in the county.

For an analysis of the water, *see* p. 302.

Stoke Poges.

Ordnance Map 255, new ser. (Bucks. 38, SW.) Geologic Map 7.

From Sir J. PRESTWICH's Notes.

Gravel	2	72 ft.
Blue [London] Clay ...	70	

[The London Clay is most likely sunk through at this depth.]

Stone.

Ordnance Map 237, new ser. (Bucks. 33. N.). Geologic Map 46. SW.

1. Bucks. County Asylum, westward of the village. SE. corner of Asylum. Record in Geological Survey Office, published in Jurassic Rocks, vol. v, pp. 337, 338. (H. B. WOODWARD.)

Shaft 145 ft., the rest bored. Failed to yield the water wanted.

		Thickness. Ft.	Depth. Ft.
Soil			
Portland Beds.	Shelly oolitic limestone	25	—
	Yellow sand		
	Shelly oolitic limestone		
	Yellow sand		
	Blue limestone...		
	Blue clay	145	170
	Limestone		
	Dark sand with water		
	Blue clay with fossils		
	Limestone with *Ammonites* ...		
	Limestone		
	Blue clay	45	215
? Kimeridge, Corallian and Oxford Clays.	Limestone	40	255
	Blue clay		
	Limestone		
	Blue Clay		
	Limestone		
	Blue clay	75	330
	Limestone		
	Blue clay	200	530
	Sandy clay		
	Oolitic coralline limestone ...	10	540
	Blue clay		
? Great Oolite.	Oolitic rock of various hardness ...	30	570
	Sand and pebbles		
	Oolitic rock		
	Clay		
	Oolitic rock, with fossils.		

Stone, cont.

Of this well C. S. READ says, of the beds below the Portland Beds, "with the exception of a few narrow bands of limestone, there appeared a solid bed of clay more than 500 ft. thick. At . . . 550 ft. from the surface the great oolite was found . . . This proves the total absence of the Oxford oolite and calcareous grits." *Journ. R. Agric. Soc.*, 1855, vol xvi, p. 280.

Prof. J. PHILLIPS noted that (presumably the clay) "showed zones of gryphœa dilatata and other characteristic fossils" of the Oxford Clay. Geology of Oxford, 1871, p. 297.

WOODWARD adds that "the meagre record, and the want of information concerning the thicknesses of the beds of limestone (probably in many cases septaria), render it difficult to classify the strata."

2. Bishopstone. Southern part of the hamlet?

Information got by A. J. JUKES-BROWNE from the occupier, who sunk the well and who was certain of the succession, though not of the exact thickness of each bed.

Sandy soil		about	3
[? Lower Greensand] Red sand... ...		,,	4
[? Purbeck Beds]	Rubble of stone ...	,,	2
	Blue stone with water	,,	3

} 12 ft.

Stony Stratford.

Ordnance Map 202, new ser. (Bucks. 9. S.). Geologic Map 46. NW.

1. Brick-kiln Farm. On the high road south-eastward of the town. 1885.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

Water-level 96 ft. down, August. (1885 ?)

		Thickness. Ft	Depth. Ft.
Pit (? the rest bored)		—	5
Drift and Kellaways Beds.	Drift clay	5	10
	Clay	59	69
? Cornbrash.	Stone	7	76
Great Oolite Clay.	Bands of clay and stone... ...	16½	92½
Great Oolite Limestone	Stone	13	—
	Bands of clay and stone	8	113½
Upper Estuarine Series.	Clay	12½	—
	Stone	2	—
	Clay	1½	129½
Northampton Beds.	Flaggy rock	13	142½
Upper Lias.	Stiff blue clay	27½	—
	Brown clay	23	—
	Dark sandy clay	4	197
Marlstone.	Hard rock	4½	201½
Middle and ? Lower Lias.	Blue clay	2½	—
	Stiff clay	23	—
	Fire-clay	23	—
	Hard rock	2	—
	Fire-clay	3	255

The classification is by H. B. WOODWARD; but the section differs somewhat from the one given in his Jurassic Rocks, vol. iv, p. 391 (1894), which has less detail and stops at 225 ft. In vol. v, p. 49, he adds that brackish water was found at the depth of 221 ft.

2. Waterworks, Calverton Road, 1887.

Borings made and communicated by Messrs. LE GRAND and SUTCLIFF.

Water-level 4 ft. down.

Yield 60,000 gallons a day of 10 hours. Average daily quantity (later) 72,603 gallons (Local Government Board Return of 1915).

Stony Stratford, cont.

		Thickness. Ft. In.	Depth. Ft. In.
Soil and gravel [Drift]		9 0	9 0
Great Oolite Limestone, 15 ft.	Clay	1 0	—
	Rock	7 0	—
	Sandy clay	1 0	—
	Limestone	6 0	24 0
Upper Estuarine Series, Clay		16 0	40 0
Northampton Beds ? Rock		0 10	40 10
Upper Lias, 56 ft. 8 in.	Clay with stone	51 2	—
	Stone	1 0	—
	Black clay	2 0	—
	Stone	2 0	—
	Clay	0 6	97 6
Middle Lias ? ...	Stone	6 0	—
	Clay	3 3	—
	Clay and stones	4 0	—
	Black clay	9 3	120 0

The classification is by H. B. Woodward, who published the section in 1894, Jurassic Rocks, vol. iv, p. 391.

Two shallow borings were also made.

No. 1. Water-level 3 ft. down, December, 1887.

Dug pit	4	
Gravel	6	
Limestone	8½	26 ft.
Layers of stone and clay	4½	
Clay and shells	3	

No. 2. Water-level 3 ft. down, December, 1887.

Dug pit	4	
Clay	5	
Limestone	6	
Sandy clay	1	24 ft.
Limestone	3½	
Stony clay	4½	

Also supplies part of Calverton and of Wolverton.

For an analysis of water (? from this well) *see* p. 302.

H. B. Woodward has referred to two borings for water at *Old Stratford* (Jurassic Rocks, 1894, vol. iv, p. 391, and 1893, vol. iii, p. 322). That place, however, is just over the border, in Northamptonshire; but, as the wells have not been noticed in the Memoir on the Water Supply of that county, a record will now be given, partly from notes sent by Messrs. Le Grand and Sutcliff, who made the borings in 1855. Both are "mainly through blue clay, sand, and silt (Drift, etc.) reaching 'rock' at depths of 109 and 113 ft."

One of the borings is on the Watling Street, 150 yards north-west of the county-boundary, and the other is 150 yards north-east of the Watling Street and the same distance north-west of the county-boundary.

The following particulars are from the *Northampton Herald* of 1885.

The thickness of the Glacial Drift is "a feature of considerable interest . . . as both the Oolite and the upper Lias appear to have been completely scoured away by glacial action, down on to the hard marlstone. It is in this marlstone that the spring was tapped, after penetrating only 18 in. into it (in the shallower boring), when it immediately rose to within 22 ft. of the surface . . . The tube has been driven tight into the rock, thus effectually shutting out the upper contaminated water, from which all the ordinary wells in the place are at present supplied. . . . The whole work of sinking this well 109 ft. 6 in. deep occupied less than three weeks" (issue of 25th July, 1885).

In the other boring the spring "is so strong that it flows over at 9 ft. above the surface, and would rise still higher were the pipe carried up. It is at present flowing at the rate of 240 gallons per hour." (Issue of 8th August, 1885.)

Woodward speaks of one of these borings as giving water with "sulphate of lime, carbonate and chloride of sodium, &c., 77 grains per gallon."

It is not likely that the channel of Drift which these borings point to will respect a county-boundary; but may reach across it into Buckinghamshire.

Turville.

Geologic Map 254, new ser. (Bucks. 46 W.)

Turville Grange, Turville Common [? Turville Court].
Made and communicated by Messrs. Isler and Co.
70 ft. of 6-in. tubes from 3¾ ft. down.
Water-level 330 ft. down. Supply, 400 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Made ground		3	3
[Clay with flints]	Ballast	23	26
[? Upper Chalk]	Chalk and flints	16	42
	[? Pipe of surface-deposits] Clay and sand	15	57
	Sand	7	64
	Chalk and flints	88	152
	Chalk rock	7	159
	Chalk and flints	291	450

Turweston.

Ordnance Map 219, new ser. (Bucks. 12.) Geologic Map 45, NE.

Eastward of the village, 1906 ?
Made and communicated by Messrs. Le Grand and Sutcliff.
Water-level 61 ft. 8 in. down. Yield 600 gallons an hour.

		Thickness. Ft.	Depth Ft.
Dug well (? old, the rest bored)		—	40
[? Boulder Clay]	Mottled clay	10	—
	Hard marl and clay in bands	7	57
[? Great Oolite and Northampton Sand]	Blue rock	6½	—
	Hard marl	2½	—
	Sand-rock and water (rose to 62 ft.)	5	—
	Shelly rock	2	—
	Sandy clay and shells	13	86
[Upper Lias]	Blue clay	5	91

For an analysis of the water, *see* p. 302.

Twyford, *see* Preston Bissett.

Water Eaton.

Ordnance Map 220, new ser. (Bucks. 15. SW.). Geologic Map 46, NW.

House about ⅔ mile north-east of Newton Longville. Belonged to Mr. Bailey.
From A. C. G. Cameron's notes.
Water-level 15 ft. down.

Boulder Clay	15	33 ft.
Oxford Clay	18	

Wavendon.

[Ordnance Map 220, new ser. (Bucks. 15, NE.). Geologic Map 46, NW.

1. Wavendon Towers. 450 yards south-west of the church. 1891.
From A. C. G. Cameron's notes, taken as the work was going on.
Shaft, with 4½ ft. of water.

Sandy soil	¼ to ½	28 ft.
Dark blue Boulder Clay, with pieces of Chalk of Lower Greensand, and of Jurassic septaria (with fossils)	10 to 12	
Running sand, with some water	3½	
Soft green sand	½	
Clay (with pieces of Chalk and Jurassic fossils) and sand, mixed. Water	12	

Wavendon, cont.

2. Woburn Sands. Swan Hotel.

Noted by A. C. G. Cameron.

Lower Greensand. Sand, with a bed of fullers' earth 38 ft. down. 40 ft.

According to Dr. Fletcher's Report on the Newport Pagnell Rural District, 1912, at Wavendon there are two public water supplies, one a well and the other a spring.

The village of Woburn Sands is supplied by the Woburn Sands Joint Sewerage and Water Committee, from a well in Lower Greensand at Birchmoor Farm, Apsley Guise, just across the border in Bedfordshire. Local Government Board Return of 1913, p. 174.

Weston Turville.

Ordnance Map 238, new ser. (Bucks. 34, NW.). Geologic Map 46, SW.

Farm two miles south east of Aylesbury, near Bedgrove.

Communicated by A. M. Brown, of Tring, from the account given him by the well-sinker. Classification by A. J. Jukes-Browne.

		Thickness. Ft.	Depth. Ft.
Gault.	Blue clay	51	—
	Hard rock with iron-pyrites. No water	3	54
Portland Beds ?	Clay	4	—
	Rock	5	—
	Sand with water, which rose some way	1	64

Wing.

Ordnance Map 220, new ser. (Bucks. 24). Geologic Map 46. SW.

1. Ascott. East of the village. At a low spot on the margin of the small stream at the southern border of the park.

Communicated by A. J. Jukes-Browne. Partly in Jurassic Rocks, 1895, vol. v, p. 337, and from samples seen by him.

Shaft 44 ft., the rest bored. Abandoned.

A moderate supply of somewhat saline water found at the depth of 42 ft., on penetrating a band of hard clayey rock.

Drift and Gault	44	}	189 ft ?
Stiff clay ? Kimmeridge	145 ?	}	

The notes on the samples are as follows :—

At 9 ft.	Light-grey marly clay	} Gault.	
,, 12 ,,	Grey sandy clay.	}	
,, 15 ,,	Dark shaly clay full of small shells.	} Kimmeridge Clay.	
,, 18 ,,	Blackish shelly clay, crowded with small bivalves.	}	
,, 20 ,,	Fragment of *Ammonites interruptus*, in phosphate. ? Fallen in.		
,, 21 ,,	Dark clay with shells, with a layer lighter-coloured and very hard.		
,, 24 ,,	Black clay, with shells.		
,, 27 ,,	Black shaly clay, with shells.		
,, 33 ,,	Dark shaly clay with shells.		
,, 36 ,,	Black clay.		
,, 38 ,,	Dark grey clay with shells.		
,, 42 ,,	Hard clayey rock.		

2. Lower Wing Bury, southward of the village.

Communicated by W. Mayne and Sons, of Stewkley.

Dug and bored through bluish-black clay, to hard rock, from which water is got. 60 ft.

Wing, cont.

3. Prof. A. H. Green noted a well in Wing (? unfinished) with the following section.

Gravel	12	41 ft.
Dark blue Boulder Clay	13 or 14	
Light-blue Gault clay, with phosphatic nodules; a vein of loose matter, with water, 41 ft. down	? 15	

See also under analyses, p. 304.

4. For the Wing Rural District Council. At the parish-boundary about 800 yards north-north-east from Waterloo Farm.

Communicated by Messrs. Sands and Walker, of Nottingham.

456 ft. above Ordnance Datum.

Site chosen by a diviner. No supply found. Site used for a reservoir.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift.]	Clayey soil	10	10
	Clay	10	—
	Sandy clay	10	—
	Rough gravel	10	—
	Chalky gravel	10	—
	Gravel	14	64
[Lower Greensand.]	Sand	6	—
	Sand, with little water	22	92
	Clay	48	—
	Veins of hard stones (coprolites and pyrites)	7	—
[Kimmeridge Clay, and Oxford Clay.]	Sandy clay	23½	—
	Veins of hard stone	7½	—
	Hard clay		
	Blue clay	22½	—
	Veins of hard stone	8½	—
	Blue clay, with hard stone 26 ft. down, 42 ft. down, 66¾ ft. down, 85½ ft. down	? 91	300

H. H. Sands was in doubt whether the sand was Lower Greensand. The Drift has at all events greatly cut out that formation; but one would have expected a small supply of water between 30 and 92 ft. down.

There may be Ampthill Clay here, or some representative of Corallian beds, below 140 ft. ?

Mr. Sands suggested the abandonment of the boring when it had got into the clay; but the Council decided to go on, in order to give the diviner the chance of proving his report to be correct.

For an analysis of the Wing water, *see* p. 305.

Wingrave.

Ordnance Map 238, new ser. (Buck. 29, NW.). Geologic Map 46, SW.

About 280 ft. above Ordnance Datum.

Wingrave Mead, called Thistlebrook Farm on the map. South of the village.

Communicated by Messrs. Mayne of Stewkley.

Dug 30 ft. and bored 50, through clay [Gault] to sand. A good supply of water rises up in the well.

Winslow.

Ordnance Map 219, new ser. (Bucks. 19, SW.). Geologic Map, 46, NW.

1. Bell Hotel or Eagle Brewery. In the Market Place, 1884.

Bored and communicated by Messrs. Le Grand and Sutcliff.

Classification by H. B. Woodward.

Water from presumed Kellaways beds, rose to 140 ft. down.

Winslow, cont.

		Thickness. Ft. In.	Depth. Ft. In.
Dug well (old), the rest bored		—	28 0
Oxford Clay.	Clay	46 0	—
	Stone and clay	10 0	—
	Clay	98 0	—
	Clay, stone, and shells	15 0	—
	Stone	1 0	—
	Clay and shells	2 0	—
	Stone	1 0	—
	Clay and shells	26 0	—
	Stone	1 8	—
	Clay	9 0	237 8
	Dark sand (? Kellaways) ...	9 0	246 8
	Clay	5 0	251 8
Cornbrash	Rock	5 3	—
	Stone	1 0	—
	Rock	1 0	258 11
Great Oolite Clay.	Stone	0 7	—
	Clay	2 0	—
	Rock	0 9	262 3
Great Oolite.	Stone	4 9	—
	Clay	2 6	—
	Stone	5 0	—
	Clay	0 5	—
	Stone	4 5	279 4

What seems to be a different version of the above is given in The Jurassic Rocks of Britain, vol. v, p. 335, as follows:—

Drift	238	279 ft.
Oxford Clay		
Kellaways Beds	32	
Great Oolite	9	

Wells, at five sites, noted by A. C. G. Cameron.

2. Avenue Road.

Glacial Drift	Boulder Clay	6	20 ft.
	Sand	14	

3. The Creamery, 1895.
Water stood 8 ft. in the well.

Glacial Drift	Boulder Clay.		
	Loam and sand.		
Oxford Clay.			

20,000 gallons a day used for cooling and other purposes.

4. Gasworks.
Water stands 4 ft. down, and was pumped to the newer well at the Creamery.

Soil	3	15 ft.
Glacial Drift	12	

5. Hunting Box. Sir R. Abercromby's.
Spring at bottom. Water stands 3 ft. in well.

Boulder Clay, flinty clay	15	40 ft.
Oxford Clay	25	

6. Swan Inn Field.
Two wells, both dug through 15 ft. of Boulder Clay to sand.

A letter from S. P. Wigley (January, 1908), says that the supply is entirely from wells, some of the public ones condemned and the majority fed from surface-springs (that is being shallow). The Local Government Board Return of 1915 however says that the supply is good and adequate.

See also under **Claydon, East.**

Woburn Sands, *see* **Wavendon.**

Wolverton.

Ordnance Map 202 and Geologic Map 203, new ser. Geologic Map 46, NW. (Bucks. 9, SE.).

1. Waterworks. Blue Bridge. About half-a-mile north of Bradwell Abbey (by parish-boundary).
Communicated by F. W. Webb, of the London and North Western Railway Co.
Shaft, of 9½ ft. diameter, 47 ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
Undescribed	... ...	58	58
[? Upper Lias].	White sandy clay	18	76
	Blue clay	24	100
[?Marlstone.]	Grey sandstone	5	—
	Sandy marl	1	—
	Grey sandstone	2	108
[Middle and ? Lower Lias.]	Blue clay	12	120
	Limestone	1	—
	Blue clay	35	156
	Grey limestone	2	—
	Blue clay	49	207
	Limestone	1	—
	Gypseous	1	—
	Ironstone with quartz	2	—
	Sandy clay	2	—
	Blue clay	3	—
	Limestone with shells	1	—
	Blue clay	31	248
	Nodules of ironstone	1	—
	Blue clay	7	256

The classification is doubtful.

These works belong to the London and North Western Railway Co. According to the Local Government Board Return of 1915, p. 246, the well and springs near Blue Bridge give a daily average supply of 176,000 gallons, and a further supply could be got from two borings 600 yards from Blue Bridge. "Well water good, but spring water doubtful." The supply extends to parts of Bradwell. For an analysis of the water, *see* p. 306.

2. Messrs. Le Grand and Sutcliff say they put down a boring (some time before 1890) not far from the entrance to the Recreation Ground, which did not get through the clay at 171 ft.

Wooburn.

Ordnance Map 255, new ser. (Bucks. 47, S.). Geologic Map 7.

1. Bourne End. Near the Lower Mills, about 50 yards from the Thames.
? About 1840.
Lipscombe's History . . of Buckinghamshire, Fol. *London*. 1847. vol. iii, p. 633. Bored throughout. Abundant supply from the bottom.

		Thickness. Ft.	Depth. Ft.
Gravel, with loam and blue clay		36	36
[? Upper, Middle and Lower Chalk.]	Chalk. No flints. A hard rock of white stone, 10 ft. thick near the middle [? Chalk Rock]	194	230
	Marl. "Occasionally very minute strata of slate or jet"; with "decayed vegetable matter"	150	380

The "marl" of the last mass is probably merely soft chalk. Of the "strata of slate" A. J. Jukes-Browne says, "these are doubtless the thin layers of grey marl that always occur in the Middle Chalk, and which are dark when wet."

Wooburn, cont.

2. Bourne End. Pumping Station of the Great Marlow Water Co.

Local Government Board Return of 1915, p. 194.

A deep boring (in Chalk), from which the average daily quantity got is 106,000 gallons.

For an analysis of the water, *see* p. 306.

Worminghall.

Geologic Map, new ser. Oxford, special Sheet. (Bucks. 31, SE.)

From E. Parry, Surveyor to the Rural District Council of Long Crendon, 1905.

The water in the majority of the wells rises to within about 8 ft. of the surface. The first bed found is clay, beneath which is a limestone-rock about 2 ft. thick, which yields a good supply of water. Excavations for sewer-trenches were made some two or three years before (? 1902), and it is said that the contractors had great difficulty in keeping back the water.

The clay is Ampthill Clay, and the stone may be the Arngrove stone.

T. I. Pocock has recorded that "The wells are not more than 15 ft. deep, but as a rule there is a sufficient supply of water." The Geology of the Country around Oxford, 1908, p. 128.

Wycombe, High or Chipping.

Ordnance Map 255, new ser. (Bucks. 42, SW., 47, NW.). Geologic Map 7.

T. W. Rammell, in his Report to the General Board of Health, 1850 (pages quoted 11, 17) says "The gravel in the bottom of the valley is more or less saturated with water . . . According to . . . the town-surveyor, water is obtainable at the west end of the town at three or four feet depth and at the east end at from six to ten feet."

"The water-supply . . . is obtained from private wells; with the exception of a public pump, near the churchyard . . . Of the contamination of well-water by the infiltration of noxious matters from drains and privies" there was abundant evidence.

The supply from shallow wells and springs lasted until after the date (1874) of the Sixth Report of the Rivers Pollution Commission.

Waterworks, 1876.

? About 223 ft. above Ordnance Datum.

Made and communicated by R. B. Paten, with some later particulars.

Shaft 6 ft., the rest bored.

Standing level of water 214·83 ft. above Ordnance Datum. When pumping 204·83. Returns to rest-level in 15 minutes.

Gravel	4½	}	171 ft.
Chalk and flints	166½	}	

Newer well, 370 ft. from the above? 170 ft. south of London and Oxford main road, 150 ft. west of Pann Mill, 1909?

Nearly 217 ft. above Ordnance Datum.

Communicated by the Local Government Board.

Shaft 25 ft., with concrete below, the rest bored, 16 in. diameter, lined with steel pipes for 40 ft.

Chalky gravel, with thin layers of peat and clay	25	}	165 ft.
Chalk	140	}	

Boring in field adjoining Mill on south side of Eastern Street (main road), 1910.

Made and communicated by Messrs. Duke and Ockenden.

Steel cylinders from 1½ to 26½ ft. down. 15-in. tubes from 24 to 101½ ft. down.

		Thickness.	Depth.
		Ft.	Ft.
Made earth		4	4
[River Drift] ...	Flint and grit	26	30
Chalk...	Plastic chalk	68	98
	Hard chalk	120	218

Average daily supply of the works 450,000 gallons (maximum day's consumption, up to 1911, 500,000).

The supply is extended to parts of Hughenden and West Wycombe (and ? Loudwater).

For an analysis of the water, *see* p. 307.

Wyrardisbury.

Ordnance Map 269, new ser. (Bucks. 56. SE., 58). Geologic Map 7.

1. Copper Mills.
Communicated by H. Ibotson.
To chalk, 150 ft.

2. Ankerwyke, near the Thames. At back of stables, 1906.
55 ft. above Ordnance Datum.
Bored by Messrs. Isler and Co. Communicated by A. H. Benson.
20 ft. of 7¼ in. tubes, from 6 in. down; 150 ft. of 6-in. tubes from 2½ ft. down, and 170 ft. of 5-in. tubes from 2 ft. down.
Water level 20 ft. down. Pumping 1.00 to 1,500 gallons an hour does not lower it.
Supply 3,000 gallons a day.

		Thickness. Ft.	Depth. Ft.
Made ground		1	—
[River Drift] ...	Sand and gravel	19	—
	Thames gravel	7	27
Blue [London] Clay, with claystone at 41–41½ ft. down		56½	83½
[Reading Beds, 85½ ft.]	Mottled clay	28	—
	Mottled clay and pebbles ...	8	—
	Brown clay	19	—
	Brown sand	20½	—
	Blue clay	10	169
Upper Chalk, with flints		101	270

The water has only 4° of hardness.

Postcript to Bourne End, p. 170 :—

Ye Old Thatch, 1920?
Bored and communicated by Messrs. Duke and Ockenden.
Lined with 4½ in. tubes to 50 ft.
Water-level 2 ft. down.

[River Drift]	Sand	9	110 ft
	Gravel	13	
[Upper] Chalk and flints		88	

DETAILS OF WELLS AND BORINGS.
HERTFORDSHIRE.

Abbot's Langley.

Ordnance Map 238, new ser. (Herts. 34, SW., 39, NW.) Geologic Map 7.

1. Abbot's Hill, about two miles NNW. of the village, 1870.
About 420 ft. above Ordnance Datum.
Made and communicated by R. B. Paten.
Shaft 135 ft. the rest bored. Chalk with flints, 367 ft.
This was originally described as "near Two Waters," on the other side of the river, higher up.

2. Cecil Lodge.
Made and communicated by R. B. Paten.
Shaft 200 ft., the rest bored.

Clay and gravel	15	401½ ft.
Chalk and flints	386½	

3. Nash Mill, 1845.
Communicated by S. C. Homersham.
? about 235 ft. above Ordnance Datum.
Water-level about 7 ft. down. Supply 467,000 gallons a day.

	Thickness. Ft.	Depth. Ft.
[River] Gravel	about 6	6
Chalk, with 9 layers of flints ...	,, 102	108
Chalk...	... 102	210

4. Waterworks. 1886.
Made and communicated by Messrs. Le Grand and Sutcliff.
Bored throughout. Water-level 5½ ft. down.

Top ground [soil, etc.]		5	150 ft.
[Drift]	Clay	6½	
	Gravel	6½	
[Upper] Chalk and flints		132	

The Rev. J. C. Clutterbuck has said of this place: "If, in sinking a well, of which there are many, the clay is pierced till reaching the chalk beneath, the water will disappear. At Bedmont . . . in order to clean out a large pond fed by . . . the gravel, the head . . . of the pond being cut for that purpose, the water which immediately found its way into the Chalk sensibly augmented the supply of water in the wells near at hand, though at least 170 feet below." (*Trans. Watford Nat. Hist. Soc.*, 1876, vol. i, p. 127.)

Albury.

Ordnance Map 222, new ser. (Herts. 14, SE., 22, NE.). Geologic Map 47.

1. Patmore Hall, 1872. 353·42 ft. above Ordnance Datum.
Made by G. Ingold, communicated by H. G. Featherby.

Boulder clay and gravel... ...	60	137 ft.
Chalk	77	

2. near Patmore Heath.
Shaft sunk and communicated by G. Ingold.

		Thickness. Ft.	
[Drift]	Brown clay	5	80 ft.
	Shingly gravel ...	15	
	Rough stones and chalk	9	
Chalk	Loose chalk	5	
	Chalk with flints ...	46	

Albury, cont.

3. Patmore Heath. Public Well, 1896.
Shaft made by G. Ingold. Communicated by H. G. Featherby.
352·48 ft. above Ordnance Datum.
Rest-level of water, 16th February, 1901, 110 ft. down.

		Thickness. Ft.	Depth. Ft.
Soil		1	—
[Drift]	Loamy gravel and sand ...	5	6
[Reading Beds] ...	Brown tough clay	17	—
	Fine grey sand	4	—
	Mottled clay	5	—
	Gravel	2	—
	Yellow sandy loam	2	—
	Hard grey clay	1	—
	White and black flints	1	38
[Upper] Chalk		76	114

Aldbury.

Ordnance Map 238, new ser. (Herts. 25, SE.). Geologic Map 46, SW.

1. Tring, London and North Western Railway Station.
Sunk and communicated by R. Paten.

Yellow clay and stones	8	138 ft.
Chalk	130	

2. Another (newer) well, by the Gas-house.
Communicated by E. Timmins, of Runcorn.
Well of 6 ft. diameter, 40 ft. and six-inch boring, 40 ft. in moderately hard chalk, without flints. In 1875 the water-level was 7½ ft. below the rail-level. The yield during construction was tested once at 8,160 gallons an hour; but it was found that the water got back through the fissures in the chalk: accordingly, 300 yards of water-pipes were laid, to carry it far enough away.
According to the Local Government Board Return of 1915, p. 278, the Company supplies part of the parish of Aldbury. The well is 40 ft. deep, and there are two borings, of 80 and 120 ft. Chemically the water is good.
For an analysis, *see* p. 310.

Aldenham.

Ordnance Map 256, new ser. (Herts. 39, SE.). Geologic Map 7.

1. Aldenham House. A mile NW. of Elstree.
Sunk and communicated by R. B. Paten.
About 300 ft. above Ordnance Datum.
Shaft 155½ ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
[London Clay, 100 ft.]	Yellow clay	20	20
	Blue clay	80	100
	Coloured [mottled] clay ...	20	120
[Reading Beds, 45½ ft.]	Running sand with water	24	144
	Flints	1½	145½
Chalk with flints		244½	390

The boring was deepened 100 ft. or more in 1902, by Messrs. Le Grand and Sutcliff.

2. Radlett Station. Midland Railway.
Sunk and communicated by R. B. Paten.
Shaft 60 ft., the rest bored.

	Thickness. Ft.	Depth. Ft.
Clay and stones	15	15
Rotten chalk with flints	15	30
Hard chalk with flints, with layers of rock ...	220	250

Amwell, Great.

Ordnance Map 239, new ser. (Herts. 29, SE. 30, SW.). Geologic Map 47.

1. Amwell End Pumping Station of the Metropolitan Water Board. By the railway just south of Ware Station. 1868.

About 110 ft. above Ordnance Datum.

Made and communicated by Messrs. Docwra, and from other sources.

Shaft (cylinders) 72 ft., the rest bored.

Water-level near the surface (nearly 104·94 ft. above Ordnance Datum. J. Francis, 1896). J. M. Wood has recorded it as high as 107·1 ft. above Ordnance Datum, April, 1919.

In 1851 W. C. Mylne gave the supply as 1,694,880 gallons in 24 hours. In 1893 J. Francis returned it as 1,500,000. J. M. Wood returns it as about 1,250,000.

Rough Gravel		36	419¾ ft.
[Upper Chalk]	Loose Chalk		
	Chalk and flints	383¾	
	Chalk and shells		

2. Amwell Hill Pumping Station of the Metropolitan Water Board. On the eastern side of the road (and western side of the New River) about 515 yards north-westward of the Church. 1848.

The oldest of the New River Co.'s Pumping Stations in Herts.

About 134 ft. above Ordnance Datum.

Made and communicated by Messrs. Docwra, and from other sources.

Water-level 104·78 ft. above Ordnance Datum. Yield 3,250,000 gallons a day. (J. Francis, 1896). J. M. Wood returns it as about 3,000,000; but it varies slightly.

Well 82½ ft., the rest bored. Given as 160 ft. deep; but J. M. Wood (to whom we are indebted for much information on the New River Wells) having cleared it out, made the depth only about 148¾ ft.

All in chalk (? except soil, 2 ft.). With headings of a total length of 376 ft.

It has been recorded of this well that in enlarging it "for the reception of a pair of larger pumps, a far more copious spring was cut, which, until that moment, had been enclosed by a wall of chalk of trifling thickness." *Proc. Inst. C.E.*, 1877, vol. xlvii, p. 163.

For an analysis of the water, *see* p. 310.

For a note on the waters of these two wells, *see* p. 311.

3. Amwell Marsh No. 1 Pumping Station of the Metropolitan Water Board. By the eastern side of the New River, about 425 yards east-south-eastward of the church. 1885.

About 103 ft. above Ordnance Datum.

Made and communicated by Messrs. Docwra, and from other sources.

Well 109 ft., with a heading (6½ ft. high,) at the bottom 336 ft. long, the rest bored, 23 in. diameter.

Water-level 4 ft. down. Given as 104·15 ft. above Ordnance Datum (at which level it overflows) by J. Francis, 1896.

Yield 2,800,000 gallons a day. J. Francis, 1893.

To Chalk	15	392 ft.
Chalk	377	

Several fissures were found in the northern heading; a large one at the end, giving almost the whole of the water.

4. Amwell Marsh. No. 2. 60 yards north of No. 1.

Communicated by J. M. Wood.

Two bore-holes, of 5¼ ft. diameter at top and 4 ft. at bottom, 109 ft. deep, carried down into the original heading from No. 1. Particulars as in No. 1.

Total pumping capacity (of the two) 7½ million gallons in 24 hours. Total yield about 6 million.

Water rises rapidly on cessation of pumping. Pumping here affects Amwell springs, Amwell Hill Well, and Chadwell spring.

For an analysis of the water, *see* p. 311.

5. Local Supply.

Local Government Board Return of 1915, p. 278: "Well in Chalk, Hailey Brickfields. The average daily quantity of water obtained is 700 gallons." Quality good.

Amwell, Little.

Ordnance Map 239, new ser. (Herts. 29, SE., 30, SW.). Geologic Map 47.

1. Haileybury College, Hertford Heath (Herts. 36, NE.). 1809.
Communicated by the Rev. E. H. Bradley, Head Master.

To Chalk	about 150	Depth
[Upper] Chalk	,, 50	204 ft.

F. W. Headley, Science Master, has written that he had been down this old well, which was disused, and thinks that the depth to the Chalk is much less, ? 90 ft.

J. M. Wood records the water-level on 10th June, 1920, as 173 ft. down, with 29 ft. of water.

2. Hailey Hall. By the main road southward of Great Amwell (Herts. 37, NW.). 1887.
Made and communicated by Messrs. Le Grand and Sutcliff.
Water-level 67 ft. down, in August, 1887.

Pit (the rest bored ?)		9¾	99¾ ft.
[Drift or Reading Beds]	Clay	7	
	Sand and gravel	28	
[Upper] Chalk and flints		55	

3. Vicarage. Hertford Heath.
Made and communicated by Messrs. Merryweather.
Water struck at 204 ft., rose to 198 ft. down. Good supply.

		Thickness. Ft.	Depth. Ft.
Mould		1	1
[Drift] Gravel		9	10
[London Clay, 98 ft. ?]	Brown clay	18	—
	Dark clay	66	—
	Brown clay with sand [? basement bed] ...	14	108
[Reading Beds] Light-coloured loamy sand		27	135
[Upper] Chalk		95	230

Ardeley, or Yardeley.

Ordnance Map 221, new ser. (Herts. 13). Geologic Map 46, SE.

Three wells, from A. C. G. Cameron's notes, with an addition to No. 3.

1. Cromer Mill, a mile west of Ardeley church. (There is a Cromer church also.)
At its driest water stands 3 to 4 ft. in the well, rising in wet seasons.

Bricked, in clay and stones	30	140 ft.
Chalk	110	

2. Cromer Windmill, half a mile north-eastward of the hamlet of Cromer. About 1880 ?
Often loses its water.

Close-grained loam	25	145 ft.
Chalk	120	

If the above section be right, there must be an error in R. E. Middleton's statement that this well "does not penetrate the chalk water basin." *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 564.

3. Public Well. 1883. Deepened afterwards ? Level of Curb 406·32 ft. above Ordnance Datum. Water-level, February, 1893, 129 ft. down, but sometimes lower. Had been dry twice.

Bricked, in clay and stones	30	130 ft.
Chalk	100	

U. A. Smith notes a well on the premises of E. Boorman (? 2 above), sunk about 1880 into Chalk to a depth of about 110 ft, which originally gave an ample supply. Then the water-level began to go down and the well had to be deepened five or six times, but nevertheless the supply nearly failed in 1891. In another well half a mile off, sunk in 1877, the water-level has also gone down. *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 409. R. E. Middleton (*Ibid.*, p. 354) suggests that the well was originally of insufficient depth. Other wells are noted on p. 629.

Ashridge, *see* Little Gaddesden.

Ashwell.

Ordnance Map 204, new ser. (Herts. 4, E.). Geologic Map 46, NE.

For the Ashwell Rural District Council. 600 yards south of the parish-church. 1911.

Communicated by the Local Government Board.

? 251·24 ft. above Ordnance Datum.

Water-level 152·74 ft. above Ordnance Datum. Another account says 96 ft. down.

Yield, as found by continuous pumping for 14 days, 70,000 gallons a day. Another account says 75,000, which only lowered the water-level 2 ft. Pumping at double that rate did not empty the well. Average daily supply only 8,500 gallons.

Well 103 ft., with two 10-in. boreholes.

		Ft.	In.	
Loam		1	6	
[Middle ?] Chalk		6	6	
(Melbourn) Hard rock		2	0	
[?Lower Chalk]	Soft Chalk	13	9	113 ft.
	Hard Chalk	67	7½	
	Soft Chalk	4	7½	
	Hard Chalk	17	0	

For analysis of the water, *see* p. 312.

Aston.

Ordnance Map 221, new ser. (Herts. 13, SW., 21, NW.). Geologic Map 45, SE.

1. Aston Bury. ¾ mile south of Aston church.

Made and communicated by Messrs. Duke and Ockenden.

Well 13 ft. Bored to 200, through Chalk and flints. 6-in. tubes to 96 ft. down. Water-level 98 ft. down.

A. C. G. Cameron has noted that plenty of water, but not very good, was got in a well through 15 ft. of running sand.

2. Aston End.

Noted by W. Topley.

	Ft.	
Boulder Clay	15	55 ft.
Chalk	40	

3. Rectory. 1886.

Made and communicated by Messrs. Tilley.

Water-level 75 ft. down.

		Thickness. Ft.	Depth. Ft.
[Drift]	Gravel	16	16
	Yellow clay	4	20
	Blue clay	12	32
	Sand and sandstone	45	77
Chalk		30¼	107¼

According to R. E. Middleton (*R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 632) the level of the curb is 312·51 ft. above Ordnance Datum; the water-level in February was 223·93 and in March 225·84, and the well is never dry.

Ayot St. Lawrence.

Ordnance Map 239, new ser. (Herts. 20, SW., 28, NW.). Geologic Map 46, SE.

From A. C. G. Cameron's Notes.

Clay and flints, to Chalk 25 ft.

Ayot St. Peter.

Ordnance Map 239, new ser. (Herts. 28, N.). Geologic Map 46, SE.

1–4 from A. C. G. Cameron's Notes.

1. Ayot Green. Public Well.
Heavy (Eocene) clay, 20 ft.
Sand, gravel and water.

2. Cromemyde Farm. (Information from the tenant.)

Clayey gravel, bricked	20	56 ft.
Chalk	36	

Water indifferent and sometimes bad. The well is in the farmyard, and surface-liquid percolates.

3. Frythe.

Clay	15	145 ft.
Chalk	130	

4. Rectory.

Heavy clay (Tertiary)	15	184 ft.
Chalk	169	

Mr. Cameron speaks of "condemned wells" on Ayot Green.

5. 900 yards south-westward of Welwyn church.
For the supply of Welwyn village.
From the engineer in charge, to Dr. R. L. Sherlock, 1913?
In Chalk, with surface-wash, 79 ft. 53 ft. to water.
3,000 gallons an hour pumped for 40 hours a week, lowering the water-level 2 ft.

Baldock.

Ordnance Map 221, new ser. (Herts. 7, E.). Geologic Map 46, NE.

Information from H. F. Peck (A. J. Jukes-Browne).

At the south-eastern end of the town wells are dug about 60 ft., through hard chalk; but at the lower end (Clerkenwell) they are shallower, and the water sometimes overflows after heavy rain.

The public supply comes from the Garden City works, at Letchworth. The average daily quantity taken (1911) is 24,000 gallons.

Barley.

Ordnance Map 204, new ser. (Herts. 5, SW.). Geologic Map 47.

1. The Homestall, 1899.
Made and communicated by H. G. Featherby.
362 ft. above Ordnance Datum.
Shaft of 4½ ft. diameter in the clear. Top 4½ ft. dry steined.
Rest-level of water, September, 1899, 207 ft. down; February, 1900, 201 ft. down.

Boulder clay		35	214 ft.
[? Middle Chalk] ...	Loose chalk	10	
	Chalk, with very few flints and frequent layers of hard clunch	169	

Deepened in 1902.

2. Nearly in the middle of the village.
[Sir] H. G. Fordham. *Trans. Herts Nat. Hist. Soc.*, 1888, vol. v, pp. 20–22.
Level of curb about 305 ft. above Ordnance Datum.
Middle Chalk, 165 ft.
Monthly observations on the level of the water were made, with a few trifling breaks, for nearly 23 years, from January, 1864 to October, 1866, by John Pearce, and these are given in Sir G. Fordham's paper, with a Chart showing the mean monthly water-level here and at Odsey, in Cambridgeshire.
The site is far away from any large pumping station, the Royston Waterworks being about three miles off, and so the fluctuations of water-level are due to natural causes.

Barley, cont.

In the table, the last column and the last two lines were added by Sir G. Fordham, who remarks that it "shows great variations from the mean level in years of and those following excessive and small rainfalls, and it will be seen that the extreme variation in level has been as much as 78 ft.—between 2 ft. (January, 1864) and 80 ft. (August, 1879). The greatest difference in any one year was in 1869—in January, 20 ft., and in April, 57 ft., a rise of 37 ft.[1]; and the least in 1871—in January, 6 ft., and in June, 18 ft., a rise of only 12 ft." and he says that the highest mean water-level and the heaviest rainfall were in 1879, the lowest mean water-level and the lowest rainfall in 1864, which followed a year of small rainfall, that of 1863 having been only 17·87 in.

Two years later Sir G. Fordham again referred to this well in a paper just over the border, in the parish of Guilden Morden, in Cambridgeshire. (A Record of Water-level in a deep Chalk Well at Odsey Grange. *Trans. Herts Nat. Hist. Soc.*, 1890, vol. vi, pp. 31, etc. Discussion, pp. xxii, etc., 1892.) in which he gives a section showing the variation in water-level from Barley northward to the foot of the escarpment at Melbourne, four miles off, where the nearest springs occur. He remarks "In general . . . the movements of the water are slightly later . . . in the deeper wells on the higher ground at Therfield and Barley than at Odsey, while at the same time a close parallelism is maintained in the curves representing the changes of level in the three wells."

The table was reprinted in 1893, by R. E. Middleton, in *R. Comm. Metrop. Water Supply, Appendices*, p. 641, and extended. I have availed myself of this extension for the years after 1886; but there is no return for 1887 or for the greater part of 1888.

J. M. Wood has added the figures in the lowest two lines of the last seven columns on page 180.

[1] But the greatest difference in any one year, *from April to March*, is 52 ft. in 1865, 6, as noted in the paper of 1890.

Water-level in Well at Barley, showing the number of feet of water in the Well on the first of each Month.

	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
January	2	7½	30	42	36	20	28	6	11	51	29	12	—	51	48	48
February	8	7½	47	56	46	35	36	11	14	60	28	13	40	57	54	60
March	8½	9	59	60	51	55	39	12	22	69	27	15	48	66	57	69
April	14	17	54	61	51	57	46	14	26	—	27	14	57	58	54	72
May	19½	17	54	61	49	55	42	17	40	62	27	15	51	52	53	—
June	24½	15½	50	60	43	53	37	18	42	57	24	16	49	51	54	78
July	20	10	48	56	36	51	30	18	42	54	19	16	50	60	52	75
August	12	9	43	50½	31	45	25	18	37	48	15	16	42	57	48	80
September	6	7	40	48	28	42	20	14	33	45	12	17	39	51	43	78
October	9	11	38	45	24	38	16	12	28	36	10	15	36	48	39	73
November	7	15	33	42	21	34	14	9	25	33	10	16	28	42	33	72
December	8	26½	33	47	20	30	10	10	25	—	11	40	27	41	36	66
Mean for the year	11½	12¾	44	52¼	36¼	43	28½	13¼	28¾	51½	20	17	42½	53	47½	70
Rainfall at Royston, in inches	16·67	29·33	26·48	24·86	22·62	24·5	17·16	19·07	28·52	21·09	17·79	26·36	26·78	27·22	23·36	30·

Water-level in Well at Barley, continued.

	1880.	1881.	1882.	1883.	1884.	1885.	1886.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.	Average (of the whole).
January	61	—	68	63	62	20	32	34½	—	15	43½	15	53	69½	36½
February	54	69	69	—	—	18	48	39½	—	21	48	13	52	69	41½
March	57	72	69	—	—	19	51	44½	—	30	53	6	55	76½	46
April	57	78	68	75	57	27	51	47	—	39	58½	11	60	75½	48
May	54	75	—	—	—	27	51	43	—	42½	56½	14	54	71½	47½
June	53	72	66	—	—	30	57	45½	—	52	53	14	48½	—	46
July	48	69	60	66	48	30	54	44	—	52½	49½	15	46	—	43½
August	49	68	—	—	42	22	51	38½	—	57½	44½	12½	45	—	40
September	48	57	48	—	36	22	45	35½	—	54½	40½	10	44	—	36½
October	—	51	43	63	27	21	40	32½	11	43½	32	8	43	—	32½
November	57	50	40	—	—	17	—	30	12	41½	39	10	48	—	30½
December	63	49	—	—	22	24	—	31	13	46	26	24	62½	—	33½
Mean for the year	54¾	64½	59	66¾	42	23	48	39	12	41¼	45¼	12¾	51	72½	40
Rainfall at Royston, in inches	27·39	24·03	26·2	27·37	16·68	24·4	25·12	24·05	21·63	24·41	18·63	25·94	24·91	20·52	—

Barnet.

Ordnance Map 256. new ser. (Herts. 45, 46). Geologic Map 7, and new ser. London District, Sheet 1.

This is really a threefold place. There is Chipping (or High) Barnet, part of the old town on the hill, continuing to Hadley, in Middlesex; East Barnet, the village on the lower ground; and New Barnet, between and strictly belonging partly to both of the above, but overshadowing them, as a big modern growth by the railway, and presumably with no precise boundary: on the old map (7) there is no such name.

Chipping Barnet.

The one deep well here, of which we have a record, has been described in the Memoir on London Wells (p. 136), in which, however, it is put under the heading Middlesex. The description is now reproduced.

1. Barnet Workhouse, on the southern side of Well Lane, just over half-a-mile westward of St. John's Church, 1909.

410 ft. above Ordnance Datum.

Made and communicated by Messrs. TILLEY.

Diameter of bore 8 in.

Water-level 82 ft. above Ordnance Datum = 328 ft. down.

		Thickness. Ft.	Depth. Ft.
Made ground		4½	4½
Gravel (Drift)		3	7½
[London Clay, 273½ ft.]	Yellow clay	2	—
	London clay	270	—
	[Basement-bed] Rock	½	—
	[Basement-bed] Sand	1	281
	Coloured [mottled] clay	20	—
[Reading Beds, 47 ft.]	Sand and pebble-conglomerate	10	—
	Sand and pebbles, not so hard	17	328
[Upper] Chalk		—	—

The sands above the Chalk were practically dry, as was also the case in the next well, at about the same level about 400 yards northward, in Middlesex. In return for the classing of the above as a Middlesex well it is fair to include here an account of this well just within the border of that county, especially as the Memoir in question does it the injustice of saying that "no water was got from the chalk," meaning from the well: headings were more successful.

2. High Barnet Laundry. Queen's Road. 1904 ?

Notes from T. HENNELL.

Well 373 ft. deep.

To Chalk 330 ft.

At first very little water found. After making three headings, a supply of 660 gallons an hour was got; but the water contained much iron and was unfit for domestic use. Filtration was unsuccessful in getting rid of this, but softening the water got rid of the iron enough for laundry-purposes.

The first heading, at 354 ft. deep (intended to reach the borehole, which was not found) after being enlarged yielded 40 gallons an hour. The second, at 370 ft. deep and 53 ft. long, yielded no water. The third, north-eastward at the depth of 355 ft., struck a large spring 15 ft. from the well. Water also came in through the roof further on, but the work was stopped at 23 ft, the amount wanted having been got.

I have a note of a boring at High Barnet (1898) which may refer to the above.

		Thickness. Ft.	Depth. Ft.
London Clay		274½	—
[Reading Beds]	Coloured clay	23½	298
	Gravel [?]	27	325
[Upper] Chalk		131¾	456¾

Barnet, cont.

East Barnet.

1. Bohun Lodge. 1913.
Made and communicated by Messrs. Duke and Ockenden.
About 280 ft. above Ordnance Datum.
10-in. tubes to 78 ft. down, 8-in. tubes to 274 ft.
Rest-level of water 318 ft. down.

		Thickness. Ft.	Depth. Ft.
	Clay and gravel	7	7
[London Clay]	London clay	200	—
	Black [flint] pebbles	1	208
Reading Beds. 59 ft.]	Marl	26	—
	Sandy clay	14	—
	Sand	19	267
[Upper] Chalk and flints		183	450

2. East Barnet Pumping Station of the Barnet District Water Co. 1899.
From the Local Government Board and from F. J. Bancroft, Engineer to the Co.
131 ft. above Ordnance Datum.
Shaft. Cast iron cylinders of 14 ft. diameter, 25½ ft.; of 13 ft. diameter, 58¾ ft., of 12 ft. diameter, 50 ft., unlined, of 11¾ ft. diameter.
Headings, at the depth of 215 ft. (extended) 2,926¾ ft. long; at the depth of 280 ft., 95 ft. long; total 3,021¾ ft.
Average daily supply 791,000 gallons.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
	Ballast [gravel]	½	
? Wash	Clay	1½	
	Ballast [gravel]	¾	3¾
	Mixed clay	13¼	
	Dark clay and sand	24	
London Clay, 60¼ ft.	Blue clay and sand, most sand ...	5	
	Blue clay and sand	16	
	Blue clay	2	64
	Mottled clay	2	
	Blue clay	½	
	Mottled clay	8½	
Reading Beds, 64 ft.	Rock	1	
	Rock and clay	2	
	Mottled sandy clay	22	
	Black pebbles	1	
	Clay sand and black pebbles ...	26½	
	Flints	½	128
[Upper] Chalk		172	300

J. M. Wood states that the pumping at this well affects to a considerable extent the water-level in the bore-hole of the Betstile Well of the Metropolitan Water Board, about a quarter of a mile to the south, in Middlesex.

3. Oak Hill, Mr. C. E. B. Young's. 1915.
Bored and communicated by Messrs. Duke and Ockenden.
Lined with 4½ in. tubes to 290 ft.
Water cut at 336 to 343 and 431 to 436 ft. down.
Tested at 480 gallons an hour.

	Thickness. Ft.	Depth. Ft.
London Clay	204	204
Reading Beds	30	234
Thanet Sand [?]	26	260
[Upper] Chalk and flint ...	190	450

New Barnet.

Barnet District Water Co. Close to the county-boundary, by the western side of the Great Northern Railway.
Statement in *R. Comm. Metrop. Water Supply. Appendices* 1893, p. 526. *Return as to Water Undertakings, Local Government Board*, 1915, p. 176, and from F. J. Bancroft, Engineer to the Co.

Barnet, cont.

Three wells, about 213 ft. above Ordnance Datum, connected by headings All now 314 ft. deep, and of 9 ft. diameter, or thereabout. Average daily supply 293,000 gallons. In 1874 the supply from the Waterworks well was given as 144,000 gallons a day, in *6th Report Rivers Pollution Commission*, p. 308: it was then the chief source of supply.

A section, from R. C. TRENCH'S note-book, defined only as near the railway-station, seems to be another version of the deeper of the following records of these wells. Mr. BANCROFT tells me that he knows of no other in such a site. It gives the London Clay 115 ft., the Reading Beds 44 and the Chalk 280: it seems useless to reprint the details from the Geology of London, etc., vol. ii, p. 44.

1. Waterworks, 1876.
Sunk and communicated by Messrs. T. DOCWRA and SON (drawing).
Shaft 171 ft. (now 314), the rest bored.

		Thickness. Ft.	In.	Depth. Ft.	In.
[Surface deposits.]	Ashes and made ground	1	3		
	Yellow clay and gravel	2	0	3	3
	Yellow clay	2	0	—	
	Yellow and blue clays	5	0	—	
	Yellow clay, with a 6-in. bed of claystone [septaria] at top ...	16	0	—	
	Yellow and blue clays, with 6-in. bed of claystone at top	4	0	—	
	Blue clay, with 5 beds of claystone, from 2 to 10 in. thick	45	6	—	
[London Clay, 113¾ ft.]	Blue clay and dark sand, with a 3-in. bed of claystone at bottom ...	6	9	—	
	Blue clay	6	0	—	
	Dark sand	6	0	—	
	Blue clay	9	0	—	
[Basement-bed.]	Blue clay and sand, with a small vein of shells	5	0	—	
	Dark sand with water	8	0	—	
	Pebbles	0	6	117	
	Mottled clay	13	0	—	
	White sand	4	0	—	
	Yellow and green sand	3	6	—	
[Reading Beds, 50 ft.]	Pebbles	2	0	—	
	Red sand	4	0	—	
	Pebbles	2	0	—	
	Spring sand	20	0	—	
	Green flints	1	6	167	
	Mild chalk, with an 18-in. layer of hard grey flint	11	6	—	
	Chalk, with 7 layers of flints, from 5 to 12 in. thick	30	5	—	
	Very soft chalk, with very hard flints at bottom	5	7	—	
	Chalk, with 4 layers of flints, from 4 to 9 in. thick	35	8	250	2
	Chalk and flints	10	0	—	
[Upper Chalk, 293½ ft.]	Chalk, with a 10-in. layer of grey flint in the middle	10	4	—	
	Chalk and flints	10	6	—	
	Chalk, chiefly sticky, with a flint layer	13	0	—	
	Soft chalk, with a 30-in. layer of very hard flints near the top, and a thin layer below	8	3	302	3
	Chalk, with a 9-in. flint layer at top and at bottom	7	6	—	
	Chalk, chiefly soft, with a flint layer	10	6	—	
	Very hard chalk and flints	2	0	—	

Barnet, cont.

		Thickness. Ft.	In.	Depth. Ft.	In.
[Upper Chalk, 293½ ft.]	Chalk, with 2 layers of flints in the lower part	11	1	—	
	Hard chalk with few flints	7	0	—	
	Chalk, with 12- and 9-in. layers of hard flints at top and at bottom	3	9	—	
	Chalk and hard flints (12-in. layer at bottom)	7	0	351	1
	Hard chalk, with flints at bottom	2	6	—	
	Hard chalk and flints	4	0	—	
	Chalk, with hard flints at bottom	3	10	—	
	Soft chalk, with few flints	4	0	—	
	Hard chalk and flints, with a foot of soft chalk in the middle	6	6	—	
	Soft, and mostly sticky, chalk, with three layers of flints, and 2 ft. nearly all flints at bottom	18	9	—	
	Dark soft marl	3	0	—	
	Very hard blue stone	1	3	—	
	Soft grey chalk, partly flints, and with two flint layers in the lower part.	13	3	408	2
	Very hard flints, with soft veins of chalk	3	4	—	
	Soft chalk, with few flints; a flint layer at top	3	3	—	
	Very hard grey chalk, with few flints	15	0	—	
	Very hard grey chalk, with one flint layer	26	2	—	
	Lighter-coloured chalk	4	6	460	5

In the drawing the depth to the Chalk is given as 168, and the total is given as 461½ ft. There may be some error in the details therefore.

2. Trial-boring for the Waterworks.

Made and communicated by Messrs. T. Docwra & Son.

		Thickness. Ft.	Depth. Ft.
[London Clay, 111½ ft.]	Yellow clay	20	—
	Blue clay	80	—
	Dark green sand [basement-bed ?]	11½	111½
[Reading Beds 58 ft.]	Loose sand, with water[1]	6	—
	Pebbles[1]	1	—
	Coloured [mottled] clays	17	—
	Hard light-coloured sand	7	—
	Pebbles	1	—
	Clunch [? hard clay]	2	—
	Dark firm sand	3	—
	Pebbles	1	—
	Sand, with little water	1	—
	Pebbles	4	—
	Dark sand	12	—
	Lighter-coloured sand	3	169½
[Upper] Chalk		14	183½

[1] [These may belong to the basement-bed of the London Clay.]

Barnet, cont.

The following summary of the record of the level of the water at these works has been given by T. H. MARTIN, the former Engineer. 1893 :—

Depth below centre of Engine-shaft, 4½ ft. above door-step.

Year.	Average.	Highest.	Lowest.	Fallen.	Total Fall.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1874	150—6	—	—	—	—
1876	159—8	—	—	9—2	
1880 ?	158—6	—	—	+1—2	8—
1884	166—8	165—10	167—	8—2	16—2
1885	169—2	166—3	170—4	2—6	18—8
1886	170—11	168—11	172—5	1—9	20—5
1887	173—5	170—9	174—7	2—6	22—11
1888	175—3	173—8	176—7	1—10	24—9
1889	176—9	175—4	178—2	1—6	26—3
1890	177—11	176—9	178—9	1—2	27—5
1891	179—10	178—	181—6	1—11	29—4
1892	182—5	180—5	184—8	2—7	31—11
1893	184—3	182—4	189—6	1—10	33—9

Since 1884 the measurements have been taken after from 12 to 26 hours' cessation of pumping.

Measurements made in July, 1892 :—

4th.—After 26½ hours cessation from pumping, water-level 182 ft. down. After 10 hours 55 minutes pumping, 230 ft. Fall 48 ft.

11th.—After 23¾ hours cessation from pumping, water level 182 ft. 5 in. down. After 9 hours 55 minutes pumping, 232 ft. Fall 49 ft. 7 in.

25th.—After 24 hours 5 minutes cessation from pumping, water-level 182 ft. 7 in. down. After 10 hours pumping, 224 ft. Fall 41 ft. 5 in.

Mr. Martin adds that by running both engines and pumps the water may be lowered to 257 ft.

The Barnet District Water Company supplies many places besides Barnet, including parts of the parishes of Northaw, North Mimms, Ridge, and Shenley, in Hertfordshire, and others in Middlesex.

With the exception of that at Potters Bar, which is in Middlesex, near the county-boundary, the wells are in Hertfordshire ; but the pumping station at New Barnet is just on the boundary with Middlesex.

The Potters Bar well has much the lowest yield (53,000 gallons a day).

The total daily average supplied is over 2,100,000 gallons.

The water is remarkably pure. For analysis, *see* p. 313.

From the Local Government Board Return of 1915, p. 176.

3. Lion's Down of the older map, a little South-West of the railway-station. ? Lyons-down Road of the 6-in. map.

From BLENKARN's "Architectural Specifications," *London,* 1865. Particulars added from a Drawing communicated by the late G. COOPER.

About 290 ft. above Ordnance Datum.

Shaft and iron cylinders to 122 ft. (about half of each) ; the rest bored.

Water rose to a height of about 130 ft. below the surface of the ground.

			Thickness.	Depth.
			Ft.	Ft.
[London Clay.]	Yellow clay		20	—
	Blue clay		80	—
	[Basement-bed.]	Greenish sand ...	11½	—
		Quicksand and water with large stones ...	½	—
		Pebbles ...	1	113

Barnet, cont.

		Thickness. Ft.	Depth. Ft.
	Coloured [mottled] clay	17	—
	Hard light-coloured sand	7	—
	Pebbles	1	—
	Coloured [mottled] clay	2	—
	Dark dead sand	3	—
[Reading Beds.]	Pebbles	1	—
	Light-coloured sand and a little water	1	—
	Pebbles	4	—
	Dark compact sand	12	—
	Lighter-coloured sand [a foot of flints at the base]	3	164
Chalk.	Without getting water, 170 ft. At "275 ft. below the bottom of the well" (= 397 ft. down[1]) very hard. At a depth of 220 ft. in the chalk a soft bed, 10 ft. thick, at the bottom of which was dark sand, a few inches thick, yielding plenty of water	230?	392 ?

The drawing differs also in showing a foot, apparently of soil, at the top, and in describing the top of the Basement-bed as greenish sand, 12 ft.

[1] This seems too deep. Perhaps it is meant to be 275 ft. below the bottom of the brickwork, which would be at a depth of 335 ft.

4. The Absorbing Well (for the sewage) J. BLENKARN, *The Builder*, March 18, 1865, p. 189. Fortunately not used now. *See* p. 96.

		Thickness. Ft.	
[London Clay, with a wash of gravel, 73 ft.]	Superficial gravel and yellow clay ...	20	
	Clay	46	
	Dark shelly clay[2]	5	
	Grey sands, pebbles, with water [basement-bed ?]	2	
	Mottled clay	23	
	Green sand	9	141 ft.
	Brown sand	5	
[Reading Beds 68 ft.]	Hard pebbles (conglomerate) ...	8	
	Fossil wood and sand	9	
	Hard pebbles and quicksand (free light-coloured sand), level of water-bearing surface	14	

[2] [May belong to the basement-bed.]

Batchworth, *see* **Rickmansworth.**

Bayford.

Ordnance Map 239, new ser. (Herts. 36, NW.). Geologic Maps 7 and 46, SE.

Near the church.
From R. C. TRENCH's Note-book.
In Chalk at 150 ft.

Beaumont Green, *see* **Cheshunt.**

Bengeo Rural.

Ordnance Map 239, new ser. (Herts. 29). Geologic Map 46, SE.

Herts. Reformatory. From Dr. R. L. SHERLOCK.
Well about 50 ft. Gravel about half-way down. Large supply.

Benington.

Ordnance Map 221, new ser. (Herts. 21, N). Geologic Map 46, SE.

From A. C. G. Cameron's Notes. Information from Messrs. Cox and Savage, well-sinkers.

1. Benington Place.
Good supply. Water 30 ft. in well.
Blue loam, bricked 40
Chalk ... ... 130 } 170 ft.

2. Park Cottages.
Water stands 18 ft. in the well.
Blue loam, bricked 30
Chalk ... ... 126 } 156 ft.

3. Public well.
A shaft. Since bored deeper. Water 8 ft. in the well.
Clay and stones, bricked 25
Chalk ... ... 155 } 180 ft.

4. White Horse Inn.
Water stands 24 ft. in well.
Red soil ... 10
Blue loam ... 35 } 148½ ft.
Chalk 103½

5. In the village.
Loam with flints 12
Sand and gravel, with water ... 20 } 32 ft.

Berkhampstead.

Ordnance Map 238, new ser. (Herts 33, NW.). Geologic Maps 7. and 46. SE..

1. Waterworks Company, High Street, next the Town Hall. 1866.
340 ft. above Ordnance Datum.
Sunk and communicated by R. B. Paten.
Shaft 10 ft., the rest bored.

Water stood within 8 ft. of the top. the quantity pumped being about 50,000 gallons a day, according to "A Treatise on Waterworks," by S. Hughes, p. 218 (1875), whence the figures in brackets are taken.

[Drift] { Clay ... 6 / Gravel 4 (6)
Chalk with flints ... 200 (198)

According to the Local Government Board Return of 1915, p. 194, there are two borings. "The average daily quantity of water obtained is 480,000 gallons. . . . the water is well adapted for drinking purposes." For an analysis, *see* p. 313. The supply is extended to parts of the parishes of Ashley Green and Northchurch : the limits of supply include other places.

2. Messrs. Lock and Smith's Brewery. 1876.
Made and communicated by Messrs. Tilley.

		Thickness. Ft.	Depth. Ft.
Clay and gravel		14	14
	Soft chalk	50	64
	Hard chalk	36	100
[? Middle and Lower Chalk.]	Hard chalk, with flints	50	150
	Hard chalk, with water	10	160
	Hard chalk, with flints	40	200
	Limestone	16	216
	Soft chalk	14	230
	Hard chalk	30	260

The following further particulars from U. A. Smith (*R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 403).

Surface 346½ ft. above Ordnance Datum. Top of flange of bore-pipe 345. Top of well of iron-cylinders. Large tube-well put down inside. At first water flowed over the flange-joint of the tube to 345·1 ft. above Ordnance Datum.

Berkhampstead, cont.

In the winter of 1891-92 the water-level was 338·4 ft. above Ordnance Datum; and in September, 1892, 337·38.

A decrease of water in four other wells in the town is noticed. But R. E. Middleton (*ibid.*, p. 549) credits this decrease to the pumping at the Brewery and the Waterworks, together with seasonal difference.

The subject is again taken up on p. 577 of the same volume. These four wells are all shallow.

Berkhampstead, Little.

Ordnance Map 239, new ser. (Herts. 36, W.). Geologic Map 7.

1. Waterworks (Hertford Rural District Council) on the marsh by the side of the Lea, at the N.E. corner of the parish. For the supply of Bayford.

Local Government Board Return of 1915, p. 64. Site described as at Roxford Farm, Bayford. Roxford is in the parish of Hertingfordbury, and the well is on the other side of the Lea, just outside Bayford parish.

"The average daily quantity of water available is 8,000 gallons . . . good but hard."

The well must pass through Alluvium and River Gravel into the Upper Chalk.

2. Woodcock Lodge Farm, south of the village.

About 380 ft. above Ordnance Datum.

Made and communicated by Messrs. A. Williams and Co.

Shaft 33 ft., the rest bored.

Water rose to within 260 ft. of the surface.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift.]	Blue clay [? Boulder Clay]	12	—
	Sandy ballast [Gravel]	3	15
[London Clay, 154 ft.]	Blue clay	58	—
	Blue clay and claystones	15	—
	Blue clay	73	—
	Green sand and clay [basement-bed ?]	8	169
[Reading Beds, 60 ft. ?]	Blue clay	5	—
	Dark green sand	10	—
	Very hard green sand	17	—
	Green sand	28	229
[Upper]	Chalk and flints	221	450

No Boulder Clay is shown on the map here.

The division between London Clay and the Reading Beds is doubtful.

Bishop's Stortford.

Ordnance Map 222, new ser. (Herts. 23, W.). Geologic Map 47.

1. Apton Road. The Cemetery. 1889.

Made and communicated by G. Ingold.

Gravel	3	36 ft.
Brown clay	9	
White sandy loam ...	3	
Yellow sand	21	

2. Chantrey Road (*a*. Mr. Dodd's. *b*. Mr. Baker's).

Made and communicated by G. Ingold.

	Ft. *a*.	Ft. *b*.
Brick-earth (? London Clay)	30	30
White sand	2	2
Green sand	18	16
To Chalk	50	48
Chalk	19	14

3. Dunmow Road (Mr. Meredith's cottage).

Made and communicated by G. Ingold.

Brown loam	3	47 ft.
Gravel and sand	40	
Mottled loam	4	

Bishop's Stortford, cont.

Dunmow Road (Mr. Coote's).
Made and communicated by G. Ingold.

Boulder clay	25	
Yellow sandy loam	35	70 ft.
Green sand	10	

5. Dunmow Road (Mr. Menet's).
Made and communicated by G. Ingold.

White Boulder Clay	35	
Yellow sand	26	62 ft.
Brown clay	1	

6. Dunmow Road (Rev. A. H. Blount's).
Made and communicated by G. Ingold.

White and blue Boulder Clay	45	
Sand and gravel	15	72 ft.
Green sand	12	

7. Fox Brewery. Bailey Bros., 1907.
Bored and communicated by Messrs. Isler and Co.
Water-level 77 ft. down. Yield 5,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Soil		6	6
	Brown clay	4	—
	Boulder clay and hard chalk, mixed	7	—
	Boulder clay	40	—
	Flints	1	—
[Boulder Clay.]	Boulder clay	4	—
	Chalk boulders	1	—
	Dark boulder clay	6	—
	Chalk boulders	2	—
	Dark boulder clay	8	—
	Brown boulder clay	4	83
[Reading Beds.]	Brown clay	8	—
	Green sand	3	94
[Upper Chalk]	Chalk	80	—
	Flints	2	—
	Chalk	74	250

8. Gasworks, and Anchor Malting. 1873.
Made and communicated by G. Ingold.
Water 4 and 3½ ft. down respectively.

To Chalk ...	135	160 ft.
Chalk ...	25	

9. Grange Road. 1869.
Made and communicated by G. Ingold.
Strong spring. Water 30 ft. down.
Dip of beds 20° W.

[? Drift.]	Gravel	11	32 ft.
	White clay	2	
	Gravel	5	
	Sharp sand	6	
	Loam	2	
	Sand	4	
	Gravel	2	

10. Hadham Road (Mr. Mortlock's).
Made and communicated by G. Ingold.

Clay (? London)	25	
White sand [? basement-bed]	2	70 ft.
Green sand. Reading Beds	20	
Chalk	23	

11. Hadham Road (Mr. Portway's).
Also from G. Ingold.

Brickearth and green sand	28	44 ft.
Chalk	16	

Bishop's Stortford, cont.

12. Hawke and Co.'s Brewery. 1845.
Made and communicated by G. Ingold.
Shaft 19 ft., the rest bored.
Water 9 ft. in the shaft. Pumping 108 gallons a minute lowered the water to 4½ ft., at which it remained.

To Chalk ...	about	50	199 ft.
Chalk ...	,,	149	

13. Hockerill. The Crown yard.
Made and communicated by G. Ingold.

Made ground (or loam ?) ...	10	60 ft. to Chalk.
Sand and gravel [Drift] ...	20	
Clay [? Tertiary]	30	

14. Training College, Hockerill. 1859.
Communicated (to W. H. Penning) by G. Ingold, well-sinker.
Shaft 85 ft., the rest bored.
Water from 5 to 7 ft. deep in the shaft. Good supply.

		Thickness. Ft.	Depth. Ft.
[Drift]	Boulder clay	45	—
	Yellow sand	20	65
[Reading Beds, 25 ft.]	Green sand	10	—
	Blue clay	15	90
Chalk		120	210

15. Boring at Hockerill Vicarage (Dr. A. Irving). 1895.
Made and communicated by G. Ingold.

		Thickness.	
Mould		1	
[Glacial Drift.]	Stony [Boulder] clay	7	28 ft.
	Brown loam	8	
	Fine gravel	10	
	Hard gravel	2	

16. Local Board Sanitorium, a mile south of the town.
Sunk and communicated by G. Ingold.
Shaft 15 ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
Made ground		8	8
Gravel and sand		2	10
[London Clay, 12 ft.]	Grey and red sandy loam	2	—
	Yellow sandy loam ...	6	—
	Stiff brown clay, with red sand in the bottom foot	4	22
[Reading Beds. 52 ft.].	White marly clay ...	5	—
	White sandy clay ...	3	—
	Greenish-grey sand ...	14	—
	Brown clay	2	—
	Dark green clay... ...	1	—
	Brown clay	5	—
	Bright green loam ...	1	—
	Yellow sandy clay ...	6	—
	Brown clay	1	—
	Slate-coloured clay ...	8	—
	Dark clay, with green veins and black pebbles	1	—
	Dark sandy clay, with white veins	4	—
	Dark green sand ...	1	74
Upper Chalk		30	104

17. New Road (Mr. J. Woolston's garden).

	Thickness. Ft.	Depth. Ft.
Drift gravel	10	10
Brickearth (? London Clay)	30	40
Greensand (Reading Beds)	16	56
Upper Chalk	21	77

Bishop's Stortford, cont.

18. Nonconformist Grammar School. 1894.

Made by G. Ingold. Communicated by H. G. Featherby.

Shaft 70 ft., the rest bored.

Rest-level of water 60 ft. down.

Yield 35 gallons a minute, lowering the water 3 in. only.

		Thickness. Ft.	Depth. Ft.
[? London Clay] ...	Brown clay	7	—
	Bluish-brown clay	1	—
	Reddish-brown clay	3½	—
	Light-brown sandy loam ...	1½	—
	Brown clay	4	—
	Brown and blue clay	3	—
	Dark brown clay	4	24
[? Reading Beds] ...	Grey sand	1	—
	Hard red clay	1	—
	Red and green clay	3	—
	Greenish-yellow sand	7	—
	Slate-coloured clay	¼	—
	Grey sandy loam	3¾	—
	Brown sandy loam	3	—
	Blue sandy loam	7	—
	Yellow clay	2	—
	Slate-coloured clay with pebbles	½	—
	Flints	½	53
[Upper] Chalk ...	... ...	117	170

19. Plaw Hatch, east of the town. 1878.

Made and communicated by G. Ingold.

Shaft 87 ft. (partly old well), the rest bored.

Water-level 95 ft. down.

		Thickness. Ft.	Depth. Ft.
[Alluvium] Peat ...	... ...	?	?
Boulder Clay, with a large boulder (2 ft. thick) at 47 ft.		?	58
[London Clay, 19 ft.]	Hard brown clay	2	—
	Dark sandy clay	3	—
	Hard brown clay	14	77
[Reading Beds, 35 ft.].	Dark grey sand	2	—
	Dark clay	6	—
	Red sandy loam	?	—
	Red and green loam	6	—
	Green clay	18	—
	Flints	1	112
[Upper] Chalk, with many flints ...	... ...	100	212

There is some doubt as to the division between the London Clay and the Reading Beds.

20. Railway Station.

Made and communicated by G. Ingold.

Made earth	6	55½ ft. to Chalk.
Yellow loam	2	
Stiff brown and blue clay	4	
Gravel, with pebbles	8	
Loose sand and fine gravel	30	
Very stiff blue clay, with a large stone at the bottom	1	
Yellow loam, to Chalk	4½	

21. South Mill Malting, 1869.

Made and communicated by G. Ingold.

To Chalk	40	64 ft.
Chalk...	24	

Bishop's Stortford, cont.

22. South Road. Mineral Water Works. 1886.
Made and communicated by G. Ingold.
Bored throughout.
Water-level 14 in. down.

		Thickness. Ft.	Depth. Ft.
Made ground		5	5
[Drift]	Gravel	8	—
	Black loam	5	—
	Gravel, with water	15	—
	Grey sand	53	86
[? Drift, or London Clay ?]	Light-brown or grey clays	4	—
	Yellow sandy loam	10	—
	Sand and gravel	5	105
[? Reading Beds]	Sandy loam	2½	—
	Light-brown clay, with stones	2	—
	Strong dark-brown clay	3	—
	Clay, with layers of sand	9	—
	Gravel [? pebbles]	2	—
	Sand	9	—
	Brown clay	2	—
	Sand	9¾	144
[Upper] Chalk		43½	187½

The depth to the Chalk is greater than in any of the other wells in the town, though the well at the Gas-works approaches this depth, being 135 ft. to the Chalk. The thickness of Drift is remarkable, and Mr. Ingold thinks that all the beds above the Chalk may be Drift.

Mr. Ingold thinks that in a well at the Old London Road Malting, the account of which has been lost, we have evidence of a deep channel of Drift, like that in the valley of the Cam, in Essex (see *Quart. Journ. Geol. Soc.*, vol. xlvi, pp. 333–340). This well also bears out his idea that all the beds above the Chalk, that is to the depth of 144 ft., in the well at the neighbouring Mineral Water Works (No. 22), are Drift. It is certainly hard to understand how the older Tertiary beds should reach to such a depth here, and the section, in both cases, seems to accord more with the classification as Drift than with that as London Clay and Reading Beds. As Mr. Ingold remarks, the channel deepens southward. How much further it may go is a question needing further evidence for answering.

23. South Road, New Malting, south of Mineral Water Works, 1897.
Made and communicated by G. Ingold.
Almost wholly published by the Rev. Dr. A. Irving, *Proc. Geol. Assoc.*, 1898, vol. xv, pp. 224, 225.

		Thickness. Ft.	Depth. Ft.
Made ground		5	5
[Glacial Drift]	Gravel	1	—
	Small [fine] yellow sandy gravel	20	—
	Grey clay	1	—
	Grey sandy gravel	2	—
	Blue sandy gravel	2	—
	Blue clay	3	—
	Brown peaty clay	31	—
	Blue sandy clay	3	—
	Grey shingle, sand and stones. Thin layers of grey sandy clay at 88 ft., and of yellow at 98 ft.	30	98
	Yellow and grey sand and shingle	10	—
	Grey sand	1	—
	Grey shingle and sand	15	124
Blue [? London] clay		3	127
[Reading Beds]	Dark grey sand	17	—
	Brown sand	1	—
	Yellow sand with thin layers of loam	15	—
	Stiff brown clay and stones	10	170
[Upper] Chalk		55	225

Bishop's Stortford, cont.

24. South Street Steam Flour Mills, 1875.
Made and communicated by G. Ingold.
Shaft 17 ft., the rest bored.
Water-level 2 ft. down.

		Thickness. Ft.	Depth. Ft.
[Alluvium]	Peaty soil	17	17
[Drift]	Gravel	40	57
	Sand and gravel	34	91
[Upper] Chalk		39	130

This section seems to give evidence of a channel of Drift.

25. Waterworks. Maze Green Road. West of the town, near the farm-buildings known as Marsh Barns. 1870.
328 ft. above Ordnance Datum.
From occasional inspection during the progress of the work, by W. H. Penning.
Shaft 160 ft. (?164) the rest bored.
Water rose to within 140 ft. of the surface.
In 1897 rest-level said to be 142 ft. down.
Supply 10,000 gallons an hour. Only 25 gallons a minute (=1,500 an hour) from the bore, the rest from two headings (N. and S.) at the depth of 154 ft. The water could be pumped down to the bottom of the headings. Enough for the town (1897).

		Thickness. Ft.	Depth. Ft.
Boulder Clay	Light-brown clay	10	—
	Blue clay	7	17
	Brown clay	14	—
	Black clay	2	—
	Black sandy loam, with iron-pyrites	12	—
[London Clay]	Black clay with lignite	11	—
	[Basement-bed] Dark grey sand, with large pieces of sandstone, shells, and tooth of *Lamna*	15	71
	Black clay	2	—
	Brown clay	20	—
[Reading Beds, 45½ ft.?]	Light-brown sand	½	—
	Variegated sand	18	—
	Brown clay	4	—
	Flints and pebbles	1	116½
[Upper] Chalk		183½	300

Later information, from the Local Government Board Return of 1915, p. 18. "Two wells, 164 ft. deep, connected by adits . . The average daily quantity of water obtained is 182,045 gallons." Much more could be got. Quality good. For an analysis of the water, *see* p. 314.
In Horizontal Wells, 1874, p. 30, J. Lucas by some mistake credits the well with yielding 10,000 gallons *a minute*, and is led thereby into wrong conclusions. Such a yield is, of course, impossible.

26. Workhouse.
Made and communicated by G. Ingold.
Water rose to 85 ft. from the surface.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift]	Boulder clay	50	50
	Gravel and sand	25	75
[? Reading Beds]	Red and green loam	38	113
[Upper] Chalk		80	193

27. 200 yards south of the Church.
Made and communicated by G. Ingold.

Drift gravel	8	47 ft., to Chalk.
Brickearth [Reading Beds]	39	

28. Cottages opposite South Mill House.
Made and communicated by G. Ingold.

Gravel and sand	about 16	60 ft.
Loose drifted chalk, to hard white chalk	about 44	

29. Golf Links, about a mile from the centre of the town, on the southern side of the Dunmow Road. 1910. 125 ft. deep.

Bovingdon.

Ordnance Map 238, new ser. (Bucks. 38, NW.). Geologic Map 75.

Shantock Hall (Chantock on old map), nearly 1¼ miles SW of the village. 1904.
About 490 ft. above Ordnance Datum.
Two wells, made and communicated by Messrs. Duke and Ockenden.

No. 1. Water-level 39 ft. down.

Gravel and flints	15	75 ft.
Chalk marrow	20	
Chalk	40	

No. 2. Water-level 48 ft. down.

Chalk and gravel	4	90 ft.
Flints and marrow	20	
Chalk	66	

Bramfield.

Ordnance Map, 239 new ser. (Herts. 29, NW.). Geologic Map 46, SE.

1. The Rectory.

From A. C. G. Cameron's Notes.

[Boulder] Clay	20	160 ft.
Chalk	140	

2. Well House, south-eastward of the village, and 1,000 yards W. of Waterford.
From Dr. R. L. Sherlock's notes.
Well 103 ft. deep, with 7 to 14 ft. of water, according to season.

Braughing.

Ordnance Map 221, new ser. (Herts. 14, SW.). Geologic Map 47.

1. Braughing Bury. 1881.
Made and communicated by G. Ingold.
Shaft 17 ft., the rest bored.

Boulder clay	15	47 ft.
Chalk	32	

2. Centre of village.
Sunk and communicated by G. Ingold.
Shaft 18 ft., the rest bored.

Gravel and brown clay	8	103
Chalk with flints	95	

3. Upp Hill, for C. J. Longman. 1899 (?)
A 6 in. boring, made and communicated by Messrs. Williams and Co.
Water-level 100 ft. down. Good supply. Pumped at the rate of 300 gallons an hour.

Dug well	145	245 ft.
Boring, in chalk and flints	100	

Brickendon, *see under* Hertford.

Brickett Wood (? parish).

London and North Western Railway Station. 1914.
Made and communicated by Messrs. Isler and Co.
50 ft. of 8½ in. tubes a foot below the surface.
Standing water-level 54 ft. down.

		Thickness. Ft.	In.	Depth. Ft.	In.
Mould			6		6
[Glacial Drift.]	Clay and stones	17	6	—	
	Ballast [gravel]	15	0	—	
	Sand	2	0	—	
	Sand and stones	7	10	—	
	Small ballast [fine gravel]	2	0	—	
	Flints	1	2	46	0
[Upper] Chalk and flints		35	0	81	0

Broxbourne.

Ordnance Map 239, new ser. (Herts. 36, SE, 37 SW.). Geologic Map 1, NW.

1. T. Clark, *MS.* in *Library Inst. Civ. Eng.*
To Chalk 84 ft. Water overflowed.

2. Fishing House.
Dr. J. Mitchell's MSS., vol. 3. p. 48.

		Thickness. Ft.	Depth. Ft.
Gravel		10	10
Blue [London] Clay		30	40
[Reading Beds.]	Mottled clay	2	—
	Sand	28	70

3. Broxbourne Pumping Station of the Metropolitan Water Board. 1886. On the western side of the New River, over 600 yards NNE. of the Church.

Communicated by Mr. J. Taylor, Engineer to the New River Company.

105 ft. above Ordnance Datum. Shaft. 197 ft. No boring. Heading on E. about 400 ft., on W. about 345.

Standing-level of water 11 ft. down. (94·18 ft. above Ordnance Datum, 1896.)

J. M. Wood records the standing-level as 8 ft. down (97·1 above Ordnance Datum) on 28th February, 1909.

Great quantity of water, the temporary pumps being drowned in sinking when 2 to 3 million gallons a day were got. The yield has been returned as 4,500,000 gallons a day. J. M. Wood returns it as 3½ to 4 million a day of 24 hours.

		Thickness. Ft.	Depth. Ft.
Soil		2	2
[Valley Gravel.]	Ballast	8	10
[? Basement-bed of London Clay.]	Loamy sand	3	—
	Black silt	5	—
	Black silt, shelly	1	—
	Black silt	1	20
[Reading Beds, 40 ft.]	Blue clay	1	—
	Peat and clay	3	—
	Running sand	9	—
	Green sand	6	—
	Thin veins of dark sand and clay	20½	—
	Flints	½	60
Chalk		136	196

It is hard to make out the sandy and silty beds beneath the gravel, but, from the occurrence of shells, one is led to infer that they belong to the basement-bed of the London Clay.

4, 5. Two Borings for the New River Co.
Made and communicated by Messrs. Docwra.

4. By the Gasworks (which are just in Hoddesdon parish.)

		Thickness. Ft.	Depth. Ft.
Soil		1	—
[Valley Drift (and ? Alluvium.)]	Brown clay	1	—
	Light-blue, sandy clay	7	—
	Gravel	1	—
	Loam	1	—
	Gravel	2	13
	Peat [? lignite]	2	15
[Reading Beds, 37 ft. (? the bottom 16 ft. Thanet Sand.)]	Brown, sandy clay	2	—
	Green, sandy clay	12	—
	Green sand and pebbles, full of water	7	—
	Dark, running sand	15	—
	Flints	1	52
[Upper] Chalk		2	54

Broxbourne, cont.

5. Charlton Mill. (Hoddesdon ?)

Soil		1	
[Alluvium]	Brown clay...	1	
	Peat...	½	
Rough gravel, full of water		21	27 ft.
[? Reading Beds.]	Brown, greenish, running sand, full of water	3	
	Flints, to Chalk	½	

6. Broxbourne and Wormley Waterworks (Ware Rural District Council).

About 1904. On the western side of the New River two-thirds of a mile SSW of the Church.

Communicated by A. Williams and Co. and by Messrs. Le Grand and Sutcliff

Water-level 18½ ft. down. Yield 6,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Soil		2	2
[River] Gravel		14½	16½
[London Clay, 27½ ft.]	Brown clay	3½	—
	Blue clay	3	—
	Loamy grey sand	15	—
	[Basement bed ?] Dark clay and pebbles ...	1½	—
	[Basement bed ?] Sandy clay ...	4½	44
[Reading Beds 35½ ft.]	Mottled sandy clay	7	—
	Mottled loamy sand	7	—
	Grey loamy sand and pebbles ...	14	—
	Thanet sand [?]	6	—
	Green flints	1½	79½
[Upper Chalk] Hard flints		150½	230

A shaft put down alongside existing boring (8 ft. in diameter and 56 ft. deep) tapped the supply from the boring.

According to the Local Government Board Return of 1915, p. 148: "The average daily quantity of water obtained is 34,194 gallons" and more can be got "no indication of any objectionable impurities."

For an analysis of the water, *see* p. 314.

Buckland.

Ordnance Map 221, new ser. (Herts. 8. W. 9 E.). Geologic Map 47.

On Lord Mexborough's estate. 1887.

Made and communicated by G. Ingold.

A little water from the clay.

Mould		1	
[? Boulder Clay.]	Brown clay	8	
	Blue clay	19	38 ft.
	Brown clay	2	
	Red clay (with stones)	8	

Buntingford.

Ordnance Map 221, new ser. (Herts. 13, NE. 14. NW.). Geologic Map 47.

For the Buntingford Rural District Council. ?About a mile ESE. of the Church.

From the Local Government Board.

375 ft. above Ordnance Datum.

Water-level at commencement of pumping 279 ft. above Ordnance Datum, at cessation of pumping 258. After a 3 hours rest, following 12 days pumping, the water rose to 275·5 ft. The morning after pumping it reached rest-level.

[Glacial Drift].	Boulder Clay	14	
	Gravel, sand and flints ...	10	130 ft.
	Chalk	106	

Buntingford, cont.

The Local Government Board Return of 1915, p. 28, says:—"The average daily quantity of water obtained is 18,000 gallons" and much more could be got. The water is very good. Supplies parts of the parishes of Aspenden, Layston, and Wyddial.

For an analysis of the water, *see* p. 314.

Bushey.

Ordnance Map 256, new ser. (Herts. 44, N.). Geologic Map 7.

1. Experimental Well, in the Colne Meadows.

R. Paten. In Appendix to S. C. Homersham's "Report to the Directors of the London (Watford) Spring-water Company." Measured from plate.

Shaft decreasing in 5 stages, 34½ ft., with 4 boreholes.

About 180 ft. above Ordnance Datum.

Ordinary water-level at the surface. About 24 ft. down when supplying 1,800,000 gallons a day.

	Thickness. Ft.	Depth. Ft.
Clay [alluvium] ... ... nearly	2	2
[River] Gravel ... ... about	21	23
Black peat [?]	2	25
Chalk with 5 beds of flints	21	46
Chalk, without flints, but with many hollows (11 drawn) full of water	104	150

R. E. Middleton (*R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 599.) gives the following version—

	Ft.
Mould	1
Alluvium	1½
Peat	1
Gravel full of water	18
Soft knobly chalk	5
Hard chalk	8

This position of the peat is more likely to be right.

This well is often referred to as Stephenson's Well.

2. Colne Valley Waterworks. 1876.

W. Verini, *Trans. Watford Nat. Hist. Soc*, 1876, vol. i., pt. 5, p. 135. (Notes in brackets by W. Fox. *Proc. Inst. Civ. Eng.*, vol. xc). With some additions

About 180 ft. above Ordnance Datum.

Shaft of 10 ft. diameter 95 ft. (? 72), the rest bored (11 in. diameter).

(Yield, March, 1886, with the water 144 ft. above Datum, or 26 ft. below normal water-level, about 820,000 gallons in 24 hours. In May, 1887, this had decreased to 650,000. In 1881 the pumps were lowered 20 ft., and from 900,000 to 1,000,000 gallons were pumped in 24 hours.)

		Thickness. Ft.	Depth. Ft.
[Upper] Chalk and flints		182	182
[? Chalk Rock and Middle Chalk].	Hard rock chalk ...	12	194
	Soft chalk	3	197
	Hard rock chalk ...	16	213
	Soft chalk	1½	214½
	Hard grey rock chalk	20½	235

3. Colne Valley Waterworks. New well, 1885-7.

Made and communicated by Woodman Hill. (With some particulars, in brackets, from W. Fox, *Proc. Inst. C.E.*, vol. xc, pp. 21-27.)

Also published, by W. Verini, in *Trans. Herts. Nat. Hist. Soc.*, vol. iv, p. 116, with slight differences.

Shaft 43 ft (of 7 ft. diameter), the rest bored (18 in. diameter to the depth of 477 ft. then 15 in.). Connected with the older well by a tunnel (the floor about 59 ft. down).

Normal water-level about 20 ft. down.

The flow of water from the top of the borehole has decreased from 656,000 gallons in 24 hours, at 310 ft. below Datum, to 555,000. The first (maximum) only ran for a few days.

Bushey, cont.

		Thickness. Ft.	Depth. Ft.
[Made Ground and Soil.	Loose Chalk	4	4
	Mould	1	5
[Upper Chalk. 156 ft.]	Rotten chalk with bands of flints ...	42	47
	Chalk (soft) with seven layers of flints, two 12 in. thick, the rest 6	44½	91½
	Hard chalk, with four layers of flints, one 18 in. thick, the rest 6	26	117½
	Soft chalk, with a 12-in. and a 6-in. layer of flints	43½	161
[Chalk Rock.]	Hard grey chalk	8	169
	Soft chalk	3½	172½
	Very hard blue bind	6	178½
	Hard rock chalk	16	194½
[Middle Chalk, 267 ft. ?]	Blue clay (soft)	1	195½
	(Hard grey rock chalk) [not in Mr. Hill's account, but combined with the next.]	25	220½
	Hard chalk with thin layers of clay ...		
	Hard chalk with little clay (with thin layers of blue clay)	215½	436
	Blue clay	1½	437½
	Hard chalk	4½	442
[Lower Chalk. 255 ft. ?]	Soft chalk with little clay (with thin beds of clay)	80	522
	Hard dark chalk with clay	50	572
	Chalk Marl, 119 ft. { Dark chalk marl ... ... / Dark green sand (sand and clay) / [specimen of Chalk Marl with many green grains]	114 5	686 691
Gault [specimen of pale calcareous clay]		9	700

Some specimens were submitted to WILLIAM HILL, who examined them microscopically, and reported as follows:—

1. "The specimen from 161-169 ft. is without doubt Chalk Rock."

2. "Specimens from 178 to 194 and from 195 to 220 both agree in character with the chalk which usually underlies the Chalk Rock."

3. "A specimen from between 220 and 436 ft. agrees in character with chalk about 60 or 70 ft. above the Melbourn Rock. I feel sure that it is not below that horizon."

4. "A specimen from between 437 and 442 ft. is, I think, Lower Chalk, not very far, perhaps only a few ft., below the Melbourn Rock."

5. Of two other specimens, from 522 to 572, and from 572 to 686, Mr. HILL speaks doubtfully; but the specimen of the greenish base of the Chalk Marl seen by me can hardly be mistaken for anything else.

This brings the Chalk Rock somewhat nearer the surface than one might have expected, making the Upper Chalk rather thin. The Middle Chalk, on the other hand, is rather thick, and so also is the Chalk Marl.

As the site is a little below the oncoming of the Reading Beds, a slight addition is needed to get the total thickness of the Chalk here, which would be probably from 710 to 720 ft.

JUKES-BROWNE is inclined to doubt the position given to the Chalk Rock, thinking that it should be rather at the hard grey rock below 195 ft., and even then that the combined thickness of the Middle and Lower Chalk is too great.

The boring was begun on April 15th and finished on July 9th. The unlined part (617 ft.) was bored in 38 working days, including 10 when the work was stopped for repairs, or at an average rate of 16 ft. a day. The greatest depth bored in a day was 30 ft. (340 to 370). A trial made in September, 1886, gave the following result: first well 850,000 gallons, second 425,000, total 1,275,000. Another, in April, 1887, gave a higher result, first well 900,000, second 540,000, total 1,440,000 gallons a day.

Bushey, cont.

The following additional information is by R. B. Taylor, *Proc. Assoc. Munic. Eng.*, 1895, vol. xxi, p. 36.

The yield of the first well had decreased to 600,000 gallons a day. The combined figure given for the yield of the two wells (1,235,000 gallons a day) was a maximum, not the average, the minimum being scarcely 1,000,000.

His firm made the following changes: the engine-well (first) was lowered, to get the pump-suction lower. The deep boring (second well) was cut by a heading (floor 132 ft. down). A new pump-well was made between the other two wells, to the depth of 142 ft. Of these works "the result has been to give . . . at least three times as much water as . . . before, the available minimum yield being now (1895) well over 3,000,000 gallons per diem . . . these operations were carried out without any interruption in either the softening process (described pp. 38, 39) or the supply to the district."

The Colne Valley Water Company supplies parts of the following parishes in Hertfordshire: Aldenham, Bushey, Elstree, Ridge, St. Stephen (St. Albans R.D.), Shenley and Watford, and many others in Middlesex. The average daily quantity of water got from the Bushey Pumping Station is 3,250,000 gallons. (From the Local Government Board Return of 1915, p. 184.)

For analyses of the water, *see* pp. 315, 316.

4. Hartsbourne, Bushey Heath [S. of Clay Hill].

W. Humber. Compendious Treatise on the Water Supply of Cities and Towns, p. 47. (1876).

Clay 230
Chalk... ... 170 } 400 ft.

5. London and North Western Railway

(South of Station ? and on level of line.)

Made and communicated by R. Paten.

Surface earth	3	
Yellow clay and large stones... ...	10	96½ ft.
Chalk	83½	

6. Old (? Oak) Lodge.

Communicated by the Rev. J. C. Clutterbuck.

Water about 140 ft. down.

		Thickness. Ft.	Depth. Ft.
[London Clay, 110 ft.]	Loam and clay	25	—
	London clay	75	—
	Silt [? basement-bed in part] ...	10	110
[Reading Beds 35 ft.]	? Plastic clay	10	—
	Yellow sand ... ... about	2	—
	White sand... ... ... „	2	—
	? Plastic clay... ... ... „	6	—
	Light-green sand	6	—
	Dark green sand	? 6	—
	? ... ... about	1	—
	Flints ... ... „	2	145
[Upper] Chalk ... ... „		21	166

Cheshunt.

Ordnance Map 239, new ser. (Herts. 41). Geologic Maps 1, NW. and 7.

According to the Sixth Report of the Rivers Pollution Commission, 1874, p. 330, the supply of water for domestic purposes was then chiefly from springs. But this seems unlikely: there must have been many shallow wells in gravel.

According to T. Clark (MS. in Library Inst. C.E.) a well at Cheshunt touched Chalk at the depth of 90 ft. This is less than in any of the wells in the town now recorded, the only one under 100 ft. being No. 11, at Waltham Cross, in which Chalk was touched at 98 ft.

1. Beaumont Green, marked Beaumont Manor on the newer map. About two miles NW. of the town. (Mr. Munt's). 1833.

Dr. J. Mitchell, *Proc. Geol. Soc.*, vol. ii, p. 551. With some further particulars from a letter by J. Fort, 1886.

Cheshunt, cont.

Shaft of about 6 ft. diameter 183½ ft. Deepened by a boring.

		Thickness. Ft.	Depth. Ft.
Mould		1	1
[Drift]	Gravel	15	—
	Sand with flints	1	17
[London Clay and Reading Beds.]	Gravel clay [? meaning] ...	83	—
	Blue sand with black pebbles[1] much foul air given off ...	15	—
	Blue clay[1]	10	125
Fine soft [Thanet ?] sand		1½	126½
Chalk (spring 40 ft. down)		57	183½

[1] In Dr. Mitchell's MSS., vol. 2, p. 57, these beds are transposed.

Mr. Fort makes the total depth of well and boring about 300 ft. This may be too high.

A good supply of water was got some 12 ft. up the well. When the New River Co. started their pumping engine by the reservoir near Flamstead End (Cheshunt), this well failed whenever they pumped much, in the summer. It was then deepened, by boring 70 or 80 ft., down to the level of the New River Co.'s pump, and then there was always water, until the Company sank the deep shaft at Turnford, when a total failure took place, except at times when their engine broke down, and then the water came to this well.

The well at Burton Grange, near Hammond Street, was also injured, and Mr. Fort heard of others, too, one at Wormley End.

2. Cheshunt Common (Hammond Street), far westward of the town. High View Nurseries (F. Stevens), 1907.

Made and communicated by R. Richards and Co.

Water-level 255 ft. down.

Supply 3,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Sump-hole for pump. The rest a boring of 9½ in. diameter		—	11
[? Glacial] gravel		2½	13½
[London Clay. 134½ ft.]	Brown clay	2	—
	Black clay	90½	—
	Blue clay	17	—
	Blue sandy clay...	25	148
[Reading Beds, 48 ft.]	Black sand	10	—
	Sand and pebbles	3	—
	Gravel [pebbles] and sand ...	22	—
	Hard sand	6	—
	Black pebbles [flints ?]... ...	7	196
[Upper Chalk]	Sticky chalk and flints ...	298	—
	Very hard grey chalk	15	509

3. Cheshunt Pumping Station of the Metropolitan Water Board. Between the corners of the two old reservoirs over a mile North-West of the Railway Station. 1846. Not now used.

From Messrs. Docwra. An account by B. Latham, *Trans. Soc. Eng.* for 1864, p. 245 and pl. 5, differs in details, making the depth to the Chalk 107½ ft., and the total 171.

116·15 ft. above Ordnance Datum.

Shaft and cylinders 145 ft. (from 11½ ft. diameter down to 6, widening out to 12½ at the bottom part), the rest a 3-in. boring. Heading at base of shaft 1,650 ft. long (J. M. W.)

The yield was 750,000 gallons a day.

In 1876 the water-level was given as 82·94 ft. above Ordnance Datum.

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[1] In Dr. Mitchell's MSS., vol. 2, p. 57, these beds are transposed.

Cheshunt, cont.

	Thickness. Ft.	Depth. Ft.
Mould or surface-earth	2	2
[River] Gravel	8	10
Blue [London] Clay	40	50
[Reading Beds. 60½ ft. ?] Coloured [mottled] clay ...	3	—
[Reading Beds. 60½ ft. ?] White sand	14	—
[Reading Beds. 60½ ft. ?] Dark sand	42	—
[Reading Beds. 60½ ft. ?] Flints	1½	110½
[Upper] Chalk, with layers of flints at intervals of 3½ and 4 ft.	34½ ?	145

J. M. Wood gives the depth to the Chalk as 103 ft., and the total depth 172 ft. The thickness given to the Reading Beds seems excessive.

4. Flamstead End, Messrs. Pollard's Nursery, Longfield Lane. 1910.

Made and communicated by R. Richards and Co.

Water-level 124 ft. down.

Supply 6,500 gallons an hour.

	Thickness. Ft.	Depth. Ft.
Sump hole, for pumping-gear, the rest bored	—	12
[London Clay.] Brown clay	21½	—
[London Clay.] Rather hard blue clay ...	60½	94
[? Oldhaven Beds or Reading Beds.] Dry sand	8	—
[? Oldhaven Beds or Reading Beds.] Hard sand, with a few pebbles	4	—
[? Oldhaven Beds or Reading Beds.] Black pebbles, with a little hard sand ...	21	127
[Reading Beds. 33 ft. ?] Sand	2	—
[Reading Beds. 33 ft. ?] Green sand	9	—
[Reading Beds. 33 ft. ?] Sand	9	—
[Reading Beds. 33 ft. ?] Running sand	9	—
[Reading Beds. 33 ft. ?] Sand and pebbles ...	4	160
[Upper] Chalk and flints	152	312

5. Flamstead End, Longfield Lane. Messrs. Varney and Bonnett's Nursery, 1911.

Made and communicated by R. Richards and Co.

Water-level 190 ft. down.

Supply 6,500 gallons an hour.

	Thickness. Ft.	Depth. Ft.
Sump-hole for pumping-gear, the rest bored	—	12
[London Clay.] Brown clay	8	—
[London Clay.] Blue clay	99	119
[? Oldhaven Beds. or Reading Beds] Very dark sand and a little clay	23	—
[? Oldhaven Beds. or Reading Beds] Black sand	2	—
[? Oldhaven Beds. or Reading Beds] Pebbles	4	148
[Reading Beds, 43½ ft.] Grey sand, with traces of green sand	2	—
[Reading Beds, 43½ ft.] Grey sand and pebbles	8	—
[Reading Beds, 43½ ft.] Grey sand	20	—
[Reading Beds, 43½ ft.] Green sand	6	—
[Reading Beds, 43½ ft.] Grey sand and a few stones	7½	191½
[Upper] Chalk and flints	170½	362

6. Mr. J. Cull's Nursery, Longfield Lane.

Made and communicated by Messrs. R. Richards and Co.

Water-level (1907) 116 ft. down.

Supply 3,000 gallons an hour.

Cheshunt, cont.

		Thickness. Ft.	Depth. Ft.
Sump-hole, the rest bored		—	10½
[London Clay]	Brown clay	26½	37
	Blue clay	42	79
	Sandy blue clay ...	2	81
	Blue clay	13	94
[Oldhaven? Beds or Reading Beds?]	Black sand	3	97
	Black and green sand ...	10	107
	Solid bed of hard black pebbles	4	111
[Reading Beds.]	Green sand	30	141
	Sandstone	2	143
	Green sand	7	150
	Fine gravel [flint pebbles?]	6	156
	Green sand	2	158
	Black pebbles	1	159
	Flints	2	161
[Upper Chalk]	Chalk with few layers of flints	72	233
	Hard and very sticky chalk with many layers of hard flints	47	280

In these three Longfield Lane sections (4-6) there is some doubt as to classification, with a possibility of the presence of Oldhaven Beds.

7. Messrs. Jordy's Nurseries, a little South-West of Cheshunt Station. 1913. Made and communicated by R. Richards and Co.

70 ft. above Ordnance Datum.
Boring in chalk of 6 in. diameter.
Water-level about 20 ft. down.
Yield 2,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
[River Gravel.]	Big [coarse] ballast ...	11	11
[London Clay, 59 ft. ?]	Blue clay	13½	—
	Green sandy clay ...	16	—
	Sand and clay	20½	—
	Hard clayey sand ...	9	70
[Reading Beds. 59 ft. ?]	Mottled clay	23	—
	Green sand	11	—
	Grey sand and black sand with pebbles	12	116
	Thanet sand	13	129
[Upper] Chalk and flints		111	240

8. Newgate Street (?) by the stream about 1½ miles north-westward of Gough's Oak, 1888. For the Cheshunt Local Board.

Made and communicated by Messrs. Docwra.

Boring. Water-level 79 ft. down.

		Thickness. Ft.	Depth. Ft.
Soil		1½	1½
[Reading Beds, 45½ ft.]	Loamy clay	11½	—
	Loamy sand	11	—
	Clay with pebbles ...	22½	—
	Flints	½	47
[Upper] Chalk		109	156

According to *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 518, there is a well of 9 ft. diameter, 265 ft. deep. Then a boring of 12 in. diameter, 150 ft. deep, and headings 700 ft. long.

Flow of water into the well=1,000,000 gallons in 24 hours.

Water-level 132¼ ft. above Ordnance Datum, or 102 ft. from surface and 31 in the Chalk.

At about 10 ft. in the Chalk large fissures were found, but were empty.

Cheshunt, cont.

9. According to the Local Government Board Return of 1915, p. 36, the Urban District Council has a well and boring at Darnicle Hill (near the western border of the parish east-south-east of Newgate Street), and 101·44 ft. above Ordnance Datum. This is at the same place as the above boring. The average daily quantity of water got is 208,540 gallons, and the quality is good. J. M. Wood says that this is one of the wells from which he should expect a declining yield.

The following later information from the Clerk to the Council, through the Local Government Board (1919), refers to this, in which a well of 9 ft. diameter, 268 ft., is followed by a 12 in. boring.

		Thickness. Ft.	Depth. Ft.
Turf, 2 in.			
[London Clay] ...	Yellow mottled clay ...	21⅓	—
	Blue clay	10½	32
[Basement-bed of London Clay. In part Reading Beds ?]	Red loam, sand, shells and pebbles	10½	42½
	Loam and shells ...	20½	63
[Reading Beds.]	Sand and pebbles ...	2	—
	Sand, pebbles and oyster-shells	5	—
	Large flints	1	71
[Upper] Chalk		347	418

This section is hard to understand. Perhaps the shells in the loam between 42½ and 63 ft. down have been carried down, in which case this bed may be classed with the Reading Beds, giving that division even then a thickness of only 28½ ft. at the most, and taking the London Clay down to 42½ ft., or perhaps a little further. To give the basement-bed of this formation a thickness of 31 ft. seems excessive.

A supply in bulk is also taken from the Metropolitan Water Board, to the extent of 64,740 gallons daily average.

10. Turnford Pumping Station of the Metropolitan Water Board. On the eastern side of the New River, about 600 yards south-south-westward of Nunsbury (house). The well 1867. The deep boring 1879.

Made and communicated by Messrs. Docwra. And from specimens. Unfortunately there were none from the Upper and Middle Chalk.

Notes of those in brackets by A. J. Jukes-Browne.

The beds above the Chalk from drawings made by the New River Co.

104·92 ft. above Ordnance Datum.

Shaft and cylinders to 181½ ft., the rest bored. Headings, 418 ft. long, with floor 135 ft. down and 510 ft. long, with floor 158½ ft. down. They are of 6½ ft. diameter.

Water-level varied from 7 to 8 ft. down in January, 1885.

J. M. Wood says that the standing water-level was 72·42 ft. above Ordnance Datum on August 30th, 1908.

3,250,000 gallons a day got from the Chalk, in which, at the depth of 570 (? 576) ft., there was a fissure, causing a 34-in. chisel to drop 7 ft. J. M. Wood adds that in July, 1920, the yield was about 4,000,000 gallons a day, of 24 hours.

		Thickness. Ft.	Depth. Ft.
[River Drift] ...	Brickearth	5½	—
	Malm [? loam]	7½	—
	Gravel	10	23
[London Clay, 30ft.]	Yellow clay	¾	—
	Blue clay	15¼	—
	Blue sandy clay...	12	—
	Blue shelly clay [basement-bed]	2	53
[Reading Beds, 36 ft.]	White sand	4½	—
	Mottled clay	4	—
	Green sand with lignite ...	27½	89
Grey and black [Thanet] sand		10½	99½
Unaccounted for (? flint bed, etc., at base of Thanet Sand), the depth to the Chalk being 102½ ft. ...		3	102½

Cheshunt, cont.

		Thickness. Ft.	Depth. Ft.
[Upper Chalk, 260½ ft.]	Chalk and flints	79	181½
	Chalk, with flints at 38 levels ..	181½?	363?
	Chalk rock	15?	378
	Hard tough chalk, with a fissure from 400 to 408 ft. down ...	46	424
	Chalk rock	6	430
	Hard tough chalk	5	435
	Rock	10	445
	Hard tough chalk, many flints..	19	464
	Rock	10	474
	Very mild chalk	36	510
[? Middle Chalk 237 ft.]	Rock	5	515
	Hard tough chalk	5	520
	Rock	7	527
	Hard tough chalk	7	534
	Mild chalk	4	538
	Rock	11	549
	Mild chalk	12	561
	Rock	2	563
	Mild chalk	13	576
	Hard tough chalk. Fissure for 13 ft. from the top	20	596
	Rock	4	600
	Hard tough chalk	9	609
	Mild chalk	7	616
	Hard tough chalk	9	625
	Rock (at 630 ft., rather hard whitish chalk belonging to the top of the Lower Chalk) ...	35	660
	Very hard tough chalk. Fissure of 6 ft. from a depth of 673 ft. (at 722 ft. hard, light-grey)	68	728
	Very hard chalk rock	2	730
	Tough chalk	2	732
	Hard and tough chalk (at 733 ft., hard, light-grey; at 734 ft., soft, grey, marly; at 746 ft., very hard, whitish, gritty; at 750 and 754 ft., soft, grey, marly)	24	756
[Lower Chalk, 184 ft.]	Very hard chalk. Specimen, at 758 ft., nearly white (at 759 and 760 ft., rather hard, grey; at 762 ft., soft, grey, marly)	6	762
	Very hard chalk, darker (firm, grey, silty; at 763, 764 and 765 ft.)	3	765
	Very hard chalk	1	766
	Mild chalk (soft, dark-grey chalk marl at 770 ft.) ...	5	771
	Very hard chalk (grey at 771 ft.)	1	772
	Mild chalk (at 774 and 779 ft. mottled dark and light-grey marl)	7	779
	Inclined to change [suggestive of the glauconitic base of the Chalk Marl] (at 780 ft. rather hard, light-grey chalk; at 784 ft., grey, mottled, sandy, glauconitic marl, regarded by W. Hill as Upper Greensand)	5	784

Cheshunt, cont.

	Thickness. Ft.	Depth. Ft.
Green sand. Specimens, at 785 ft., dark grey calcareous sand; at 795 ft. lighter-grey micaceous sand (at 790 ft. soft fine-grained, greenish-grey micaceous, glauconitic sand) ...	11	795
Sandstone	1½	796½
Green sand, hard and dead (at 800 ft. hard, grey siliceo-calcareous rock)	5½	802
Sandstone. Specimens at 803 ft. grey micaceous sand, darker than the last (797)	2	804
Green sandstone. Specimen, at 806 ft., like the last	2	806
Sandstone	1½	807½
[Upper Greensand, 46 ft. ?] Darker sandstone (at 808 ft. fine, grey sand). Specimen, at 809 ft., like that at 797 ft. ...	1½	809
Hard dead sand (at 810 ft. grey, calcareous sandstone; at 811, 813 and 814 ft. soft fine grey sand)	5	814
Very hard sandstone. Specimen at 816 ft., soft grey calcareous sand (at same depth hard, compact sandy limestone; at 818 grey limestone) ...	4½	818½
Very hard dead sand (at 819 ft. grey, sandy, glauconitic marl). Specimens, from 824 ft. downwards are clay, and presumably from the Gault, so that too great a thickness must have been assigned to this bed. (But at 825 ft. fine calcareous sandstone)	11½?	830?
Gault clay (at 836,840 ft. dark grey silty clay; at 844 ft. unctuous clay; at 850 ft. somewhat silty, grey clay; 860—914 ft. ordinary Gault clay; at 925 ft. hard grey clay with phosphate-nodules: 928—980 ft. compact grey clay). At the base a layer of dark sand. At 980—980½ ft. phosphatic nodules *Inoceramus* and *Belemnites* ...	150½	980½
Devonian. Purple shale (? calcareous). The last core came up as a column 15 ft. long and about 15 in. in diameter	29½	1010

Possibly the Upper and Middle Chalk reach further down. It seems impossible to mark the division of the Chalk Marl.

The specimens examined by me were in the possession of Messrs. Docwra. Those examined later by A. J. Jukes-Browne and W. Hill were in the possession of the New River Co. It is possible that there may be some differences in the measurements of the two sets.

Jukes-Browne was led to carry the top of the Upper Greensand a foot higher and its base 3 ft. higher, thus giving it a thickness of 44 ft. and the Gault a thickness of 153½ ft.

J. Francis has treated of the dip of the Devonian rocks in detail and gives the direction, at the depth of 994 ft. as about 170 W. of S. and the angle as about 25°. *Rep. Brit. Assoc.* for 1895, p. 452. Of course the angle may be higher in places, and Jukes-Browne judged that in one specimen it might be 40°.

There are large cores of this Devonian rock in the Museum at Jermyn Street.

Cheshunt, cont.

15 trial-borings on the New River Co.'s land near Turnford Aqueduct gave the following section :—

Made and communicated by Messrs. Docwra.

Made ground, 9 ft., in one only.

Soil, from 1 to 4½ ft., in ten.

[River Drift] { Clay, or loam, from ½ to 17½ ft., in nine. / Gravel, from ½ to 13½ ft., in all but one.

Yellow clay, blue clay, coloured clay, clay and sand, sand, and in one case 3 ft. of peat, from 2½ to 20½ ft., in all but one.

11. Turnford. Nunsbury. Garden well. 1868.

Sunk and communicated by Messrs. T. Docwra and Son.

Shaft 26 ft., the rest bored. Water overflowed.

		Thickness. Ft.	Depth. Ft.
Made ground and [River] gravel		6	6
[London Clay, 27 ft.]	Blue clay	20	—
	Blue clay and sand [basement-bed ?]	7	33
[Reading Beds (and Thanet sand ?) 47½ ft.]	Coloured [mottled] clays ...	3	—
	Brown sand	2	—
	Dead white sand	10	—
	White sand and pebbles ...	4	—
	Black sand and pebbles ...	4	—
	Dark sand	8	—
	Green sand and water	7	—
	Dead black sand	9½	80½
[Upper Chalk] ... { Chalk and flints / Chalk ... }		22	102½

12. Waltham Cross. Opposite Waltham Lane. 1852. On the premises of T. Docwra.

Prestwich, *Quart. Journ. Geol. Soc.*, vol. x. p. 145, and other notes.

? About 60 ft. above sea-level.

Sunk 8 ft. the rest bored.

		Thickness. Ft.	Depth. Ft.
Mould		2	2
[Valley Drift, 14 ft.]	Loam	4	—
	Gravel	7	—
	Very rough gravel ...	3	16
London Clay, 40 ft.	Blue clay	24	—
	Blue clay mixed with dark sand	10	—
	Base-ment-bed. { Lighter-coloured blue clay and sand	5	—
	Base-ment-bed. { Black pebbles ...	1	56
	Light-green mottled sand	7	—
	White live sand	3	—
Reading Beds.[1] 51 ft.	Light-green sand, slightly mottled	1	—
	Darker green sand ...	3	—
	Green sand with flint-pebbles	3	—
	Dark green sand	7	—
	Green sand and pebbles ...	1	—
	Green sand, getting darker	16	—
	Green sand	10	—
	Flints (to Chalk)	2	109

[1] The lowest beds may perhaps belong to the Thanet Sand.

Cheshunt, cont.

13. Waltham Cross, Park Lane, Matthews' Nursery. 1907.

Made and communicated by Messrs. R. Richards and Co.

Water-level 46 ft. down. Supply 4,500 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Sump-hole for pumping-gear		—	12½
[River] Gravel		15	27½
[London Clay 68½ ft.?]	Blue clay	20	—
	Black sand	3	—
	Sand	45	—
	Pebbles	½	96
[Reading Beds]	Clay and pebbles, and green clayey sand	10½	—
	Black sand	11	117½
[Upper Chalk]	Chalk and flints	111	—
	Hard grey chalk and flints	121½	350

14. Waltham Cross, Park Lane, W. H. Miles' Nursery. 1908.

Made and communicated by Messrs. R. Richards and Co.

Water-level 36½ ft. down. Supply 4,500 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Sump-hole for pumping gear		—	12
[London Clay, 67 ft. ?]	Blue clay	24	—
	Clayey sand	39	—
	Sand and pebbles	4	79
[Reading Beds]	Clayey sand	9	—
	Sand	9	—
	Stones [flints]	1	98
[Upper Chalk]	Chalk and flints	238	—
	Hard chalk	39	375

In the last two cases again there seems a possibility that the sand and pebbles, grouped above with the London Clay, may belong to the Oldhaven Beds.

15. Waltham Cross. Springsall, near the Roman Urn.

Made and communicated by Messrs. Tilley.

		Thickness. Ft.	Depth. Ft.
[River] Gravel		13½	13½
[London Clay, 64½ ft. ?]	Blue clay	47	—
	Sand	3	—
	Sandy clay	7	—
	Stone	1¼	—
	Sandy clay	6¼	78
[Reading Beds. 64 ft. ? with Thanet Sand]	Mottled clay	6	—
	Green sand	3	—
	White sand and pebbles	15	—
	Green sand and large pebbles	12	—
	Dark sand and some pebbles (to Chalk)	28	142

Cheshunt, cont.

16. Waltham Cross. Theobalds Park. Upper Park Farm.

B. Latham, *Trans. Soc. Engineers* for 1864, p. 246 and pl. 5; and from Messrs. Docwra.

Water rose to a height of 65 ft. below the surface.

Shaft 71 ft. (? more), the rest bored.

		Thickness. Ft.	Depth. Ft.
[River] Gravel		5	5
Blue [London] Clay		59	64
[Reading and Thanet Beds, 57½ ft.]	Coloured [mottled] clays	12	—
	Dark sand	1	—
	Sand and pebbles	5½	—
	Light-coloured sand	3	—
	Dark sand	35	—
	Flints	1	121½
Chalk, 81 ft.	Chalk and flints	3	—
	Chalk	78	202½

In the drawing in Messrs. Docwra's office the total depth is given as 210 ft.

17. Waltham Cross. Theobalds Park. Newer Well. 1900.

Made and communicated by Messrs. Isler and Co.

Water-level 115 ft. down.

Yield 4,500 gallons an hour.

Lined with 175 ft. of 10-in. tubes from 10 ft. down.

		Thickness. Ft.	Depth. Ft.
Made ground		4	4
[River Gravel]	Fine Ballast	1	5
[London Clay]	Dark clay	6	—
	Brown clay	1	—
	Dark clay	30	—
	Blue clay	70	112
[Reading Beds]	Mottled clay	8	—
	Green clayey sand	10	—
	Light-coloured sand	6	—
	Dark sand and stones	3	—
	Light-coloured sand	4	—
	Dark sand	5	—
	Grey running sand	20	—
	Pebbles and sand	4	172
[Upper Chalk]	Chalk and flints	126	—
	Hard grey chalk	53½	351½

18. Waltham Cross. Theobald's Square.

Sunk and communicated by G. Ingold.

Water, from the Chalk, rose to a height of 13 ft. below the surface.

		Thickness. Ft.	Depth. Ft.
Made earth		7	7
[Valley Drift, 19 ft.]	Brown clay [Brick-earth]	8	—
	Gravel, with much water	11	26
[London Clay, 35 ft.]	Black [? dark bluish-grey] clay	32	—
	[Basement-bed.] Dark green clay with shells	3	61
[Reading Beds, 61½ ft.[1]]	Red and brown clay	4	—
	Black and grey sandy clay	1½	—
	Grey sand	18½	—
	Light-green sand	3	—
	Greenish-grey sand	8	—
	Green clay	1	—
	Grey sand	8	—
	Black clay	2	—
	Black clay with pebbles	1½	—
	Dark sandy clay	14	122½
	Layer of green-coated flints	—	—
Chalk with flints		53½	176

[1] The lowest two beds may be Thanet Sand.

Cheshunt, cont.

According to T. S. Tilley (R. Comm. Metrop. Water Supply, 1893, Minutes of Evidence, p. 238) a well at the Cedars, in Theobald's Square, was bored in Chalk 114 ft. The water-level in 1890 was 19 ft. down and in 1892 22 ft. 10 in., when at rest.

At the Nurseries (? which) there is a well, with shaft of 28 ft. and a boring, which later was deepened to 300 ft. by Messrs. Isler and Co., who tell us that the water-level was 35 ft. down, and that the minimum supply was 3,000 gallons an hour.

19. Waltham Cross and Cheshunt Gasworks. Close to Waltham Cross Station.

Made and communicated by Messrs. Tilley. 1880.

In 1880 the water flowed a foot above ground. In 1892 the water-level, at rest, had fallen to 18 ft. down.

	Thickness. Ft.	Depth. Ft.
[River] Gravel	12	12
Blue [London] Clay	43	55
[Reading Beds] Mottled clay	13	—
[Reading Beds] Sand and pebbles ...	57	125
[Upper] Chalk and flints	85	210

20. Messrs. White and Son.

Made and communicated by Messrs. Isler and Co. 1897.

Water-level 26 ft. down, when pumping 33 ft. in December, 1910.

Yield 4,000 gallons an hour.

	Thickness. Ft.	Depth. Ft.
Well (the rest bored)	—	6
[River Gravel] Ballast	8	14
Blue [London] clay	34	48
[Reading Beds, and ?Thanet Beds] Green sand	7	—
[Reading Beds, and ?Thanet Beds] Dead sand	5	—
[Reading Beds, and ?Thanet Beds] Green sand and pebbles ...	10	—
[Reading Beds, and ?Thanet Beds] Green sand	34	104
[Upper Chalk, 260 ft.] Chalk	8	—
[Upper Chalk, 260 ft.] Chalk and flints	68	—
[Upper Chalk, 260 ft.] Chalk	178	—
[Upper Chalk, 260 ft.] Grey chalk	6	364

Chipping or High Barnet, *see* Barnet.

Chorley Wood.

Ordnance Map 255, new ser. (Herts 43, NE.). Geologic Map 7.

1. Chorley Wood House.

Made and communicated by Messrs. Isler and Co.

Water-level 160 ft. down. Yield 380 gallons an hour.

Dug well (? old, the rest bored)	5	250 ft.
[Drift] Clay and large ballast [coarse gravel]	20	
[Upper] Chalk and flints	225	

2. Parsonage. 1869 ?

Communicated by W. F. Vernon and C. Brown.

Shaft throughout, 3 ft. of water.

Clay	60	164 ft
Flints	2	
[Upper] Chalk	102	

Codicote.

Ordnance Maps 221, 239, new ser. (Herts. 20, SW.). Geologic Map 46, SE.

1. For the Hitchin Rural District Council. By the side of the road 600 yards N.N.W. of the church.

Communicated by T. Hooper, Surveyor to the Council.

About 400 ft. above Ordnance Datum.

Shaft of 6 ft. diameter to 195 ft. A six-in. bore to 400 ft.

Water-level about 250 ft. above Ordnance Datum.

	Thickness. Ft.	Depth. Ft.
Clay with flints	12	12
Upper Chalk	128	140
Middle Chalk	220	360
Melbourne Rock	15	375
Belemnite Marl	5	380
Lower Chalk	20	400

The evidence seems to suggest that this well lies in an area of poor water-yielding Chalk, which extends southward and westward, but the distance is not known. To the north and north-east the yield is better. G. Barrow.

The following information got by A. C. G. Cameron.

There are land-springs at the depth of about 15 ft., and deep springs in the Chalk at about 140 ft.

2. George and Dragon Inn. In the garden.

Stony grey Boulder Clay, with chalk stones and Jurassic fossils, 33 ft.

3. At the Veterinary Surgeon's.

[Boulder Clay] Clay and stone	20	150 ft.
Chalk	130	

Cottered.

Ordnance Map 222, new ser. (Herts. 13, N.). Geologic Maps 46, NE. 47.

1. Public Well. About 1865.

R. Comm. Metrop. Water Supply. Appendices, 1893, p. 627.

Level of curb 441·39 ft. above Ordnance Datum.

Water-level 146 ft. down. Well 164 ft.

There is always plenty of water and always about the same quantity.

According to Mr. Alkern, well-sinker of Walkern, the public well is on the green, and its section is as follows:—

[Glacial Drift]	Blue [Boulder] clay and chalk-stones	50	172 ft.
	Red loam and flints ...	10	
Soft chalk, with 3 ft. of stone at the base [? Chalk Rock]		112	

2. The Rectory.

From A. C. G. Cameron's Notes.

Blue [Boulder] clay and chalk-stones ...	60	195
Chalk	135	

In October, 1889, the water stood 30 in. in the well, which had not been dry during the last 23 years.

Two wells at Hare Street are also noticed, and others in the neighbourhood, in the *R. Comm. Rep.*

Datchworth.

Ordnance Maps 221, 239, new ser. (Herts. 20, SE., 21, SW.). Geologic Map 46, SE.

Two wells, from A. C. G. Cameron's Notes.

1. Close to the church.

Clay and flints, 14 ft., to Chalk, with water at the depth of 210 ft.

2. Welches Farm, over 1¼ miles southward of the church.

Boulder Clay, with flints	15	160 ft.
Chalk	145	

Digswell.

Ordnance Map 239, new ser. (Herts. 28, NE.). Geologic Map 46, SE.

A. C. G. Cameron notes four wells, from 10 to 26 ft. deep, in Tertiary beds. Also one at the rectory, 20 ft. in gravel and then 20 ft. in Chalk. For an analysis of the water from a newer well here, bored to the depth of 320 ft. in 1914, *see* p. 316.

Eastbury, *see* Watford.

Elstree.

Ordnance Map 256, new ser. (Herts. 45 NW.). Geologic Map 7.

Boreham Wood. 1870 ?

Sunk and communicated by Messrs. S. F. Baker and Sons.

		Thickness. Ft.	Depth. Ft.
London Clay, 183 ft.	Yellow clay	20	—
	Hard blue clay	150	—
	Sandy blue clay[1]	13	183
	Sand and water	1	—
Reading Beds, 19 ft.	White pebbles	5	—
	Coloured [mottled] clay, sandy	7	—
	Clay and black pebbles, and black sand	6	202
To Chalk.			

[1] [Most likely "basement-bed"; but may belong to the Reading Beds]

Essendon.

Ordnance Map 239, new ser. (Herts, 36, W.). Geologic Maps 7 and 46, SE.

The wells are generally sunk to the depth of 270 ft., and the water rises 20 ft. T. Clark, *MS.* in *Lib. Inst. Civ. Eng.*

1. Essendon Place.

Account by Mr. T. Clark, well-borer.

	Thickness. Ft.	Depth. Ft.
Soil	2	2
Gravel and sand	24	26
Blue [London] Clay	104	130
Yellow clay [? partly London Clay, partly Reading Beds]	40	170
Flints	2	172
Chalk with flints	172	344

The account published in *Trans. Herts Nat. Hist. Soc.*, vol. iii., pt. 5, p. 176 (got by Prof. Hughes from Baron Dimsdale) differs slightly:—(1) in ignoring soil; (2) in giving no thickness to the flints at top of the Chalk; and (3) in giving 2 ft. less to the chalk, and consequently 4 less to the total.

2. Waterworks. (Hatfield Rural District Council.)

The Local Government Board Return of 1915, p. 61, says:—"Deep well at Essendon. The average daily quantity of water obtained is 9,000 gallons," and much more could be got. Quality good.

For an analysis of the water, *see* p. 316.

Flamstead.

Ordnance Map 238, new ser. (Herts. 26, NE., 27, NW.). Geologic Map 46, SE.

1. Beechwood. About two miles west of the village.

About 520 ft. above Ordnance Datum.
Made and communicated by R. B. Paten.
Shaft 80 ft., the rest bored.

Clay and gravel	20	255 ft.
[Upper and Middle] Chalk and flints...	235	

Flamstead, cont.

2. Markyate Waterworks. For the Hemel Hempstead Rural District Council, north-east of Roe End and westward of Cheverells Green, 1909?.
Communicated by Messrs. Elliott and Brown (of Nottingham) and by the Local Government Board.
538¾ ft. above Ordnance Datum.
Well 162 ft., the rest a boring of 4 in. diameter.

Water-level at commencement of pumping 397 ft. above Ordnance Datum; at cessation of pumping 391·75. Water rose to original rest-level in 1 hour and 5 minutes after pumping ceased. Yield abundant.

	Thickness. Ft.	Depth. Ft.
Clay with flints	16	16
Chalk with flints	37	53
Chalk Rock	9	62
Chalk without flints	289	351
Totternhoe Stone [? Melbourn Rock]	10	361
Chalk Marl [? Belemnite Marl]	10	371

	Test pumping. Hours.	Height of water in well.	Gallons pumped.
Tuesday, May 11... ...	24	20 ft., 3 in.... ...	47,970.
Wednesday, ,, 12... ...	24	17 ft.	47,970.
Thursday ,, 13... ...	24	14 ft., 6 in.... ...	47,970.
Friday, ,, 14... ...	24	15 ft.	47,970.
Saturday, ,, 15... ...	24	15 ,, ...	47,970.
Sunday, ,, 16... ...	24	15 ,, ...	47,970.
Monday, ,, 17... ...	24	15 ,, ...	47,970.
Tuesday, ,, 18... ...	12	15 ,, ...	23,985.

According to the Local Government Board Return of 1915, p. 63, "The average daily quantity of water obtained is 10,000 gallons," and much more could be got: "the water is of satisfactory organic purity." For an analysis *see* p. 317.

Furneux Pelham.

Ordnance Map 222, new ser. (Herts, 14, NE.). Geologic Map 47.

1. Brewery.
[Drift] Loam and fine gravel to Chalk, 30 ft.

2. Lower Farm. Eastern end of the village. 1884.
Made and communicated by G. Ingold.

			Thickness.	
[Glacial Drift]	[Boulder Clay]	White clay	7	134½ ft.
		Blue and brown clay ...	24	
		Red sand	19	
		Sand. gravel and loam	27	
Chalk...			57½	

Gaddesden, Great.

Ordnance Map 238, new ser. (Herts 26, S.). Geologic Map 46, SW.

1. Bridens Camp, eastward of Gaddesden Place.
A. C. G. Cameron's Notes.
Water stands about 5 ft. in the well.

Brickearth	20(?)	210 ft.
Chalk...	190	

2. Gaddesden Park [? Place]. 1873.
Made and communicated by R. B. Paten.
Shaft 233 ft., the rest bored.
Chalk ... ... 431 ft.

3. Gaddesden Place. Near Waterend. 1871.
Made and communicated by R. B. Paten.
Shaft 200 ft., the rest bored.

Gravel	15	385 ft.
Chalk with flints	370	

Gaddesden, cont.

4. Gaddesden Place. Grove Farm, NNE. of the house.
A. C. G. Cameron's Notes.
Shaft 200 ft. (?), the rest bored.

Strong clay	? 20	400 ft.
Chalk...	? 380	

In the summer of 1887 the water was below the pumps (? at the bottom of the shaft). When the springs are high the pumps are covered, and pumping does not lower the water-level much.

5. Gaddesden Place. Marsh Farm, about ½ mile N. of the house. 1899.
About 550 ft. above Ordnance Datum.
Communicated by Mr. T. F. Halsey, M.P. (to Sir J. Evans).

	Thickness. Ft.	Depth. Ft.
Yellow clay and breeding stones (assorted) ... about	10	10
Flint, gravel and sand	11	21
Light-coloured sand and pebbles	12	33
Dark sand and pebbles	12	45
Red coarse sand	16	61
Clay, chalk and black flints mixed. (Bricked to this depth)	10	71
Chalk and black flints	110	181
Very hard chalk	10	191
Very hard rock	7	198
Softer chalk and black flints until reaching signs of water	21	219

Up to Saturday night (14th October) there was about 1½ ft. of water.

6. Gaddesden Hoo (The Hoo, north of The Place). 1912 (?)
Made and communicated by Messrs. Duke and Ockenden.
Fissure struck 381 ft. down. Water-level 196 ft. down.
Yield 6,000 gallons an hour.

Loam and rolled flints	27	399 ft.
Chalk and flat flints	172	
Chalk without flints	200	

Gray chalk touched at 400 ft.

Gaddesden, Little.

Ordnance Map, 238, new ser. (Herts. 26, W.). Geologic Map 46. SW.

1. Ashridge Park. 1860.
Made and communicated by R. B. Paten.
Shaft 225 ft., the rest bored.

Clay and gravel	18	345 ft.
Chalk with flints	327	

2. Earl Brownlow's Well for the supply of the parish.
According to the Local Government Board Return of 1915, p. 278, the average daily amount of water got is 80,000 gallons. Much more could be got. Quality excellent. The site is over half a mile NNE. of Ashridge House.

Gilston.

Ordnance Map 240, new ser. (Herts. 30, SE.). Geologic Map 47.

Terlings, near the Stort. 1893.
Made and communicated by G. Ingold.
Water-level about that of the Stort below the Mill.

		Thickness. Ft.	Depth. Ft.
Gravel		2	2
[London Clay 51 ft.]	Hard brown clay	2	—
	Sandy loam	10	—
	Black clay	19	—
	Black sandy clay	2	—
	Hard grey clay	3	—
	Black sandy clay, with shells at the bottom	12	—
	Black peaty clay	2	—
	Black clay, with shells and pyrites	1	53

Gilston, cont.

		Thickness. Ft.	Depth. Ft.
[Reading Beds, 50 ft.]	Blue and brown clay	7	—
	Black sandy clay	4	—
	Brown-grey clay	1	—
	Brown-green clay	1	—
	Dark green sandy loam, changing to grey	36	—
	Bluish-grey clay, with flints at the base	1	103
Chalk		47	150

Gorhambury, *see* St. Albans.

Graveley.

Ordnance Map 221, new ser. (Herts. 12, NE.). Geologic Map 46. NE.

Jack's Hill. About 1830.

U. A. Smith. *R. Comm. Metrop. Water Supply. Appendices* 1893. p. 408. By mistake classed as in the Mimram Valley. Jack's Hill is in one of the arms of the Beane or in the Watershed of the Ivel.

Well of 5 ft. diameter, originally 200 ft. deep in Chalk.

Since 1878 the water has been gradually getting lower and two years ago (? 1890) the well had to be deepened 15 ft., the supply having failed. Up to about 1880 it usually contained from 20 to 30 ft. of water.

R. E. Middleton (*ibid.*, p. 562) questions this, however, and says that the "level of the water in November last was 242·22 (ft. above Ordnance Datum) and of the bottom 229·22, and the well is less than 200 ft. deep." He understood that "it was deepened about 1868 and has never been dry since."

Hadham, Little.

Ordnance Map 222, new ser. (Herts. 22, NE.). Geologic Map 47.

1. Bury Green. Acumont Farm. About a mile SSE. of Hadham Ford. (?) 1897.
Made and communicated by G. Ingold.
Water-level 90 ft. down. Slow spring.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
[? Drift or Eocene]	Yellow boulder clay	6	7
	Light-brown clay	3	—
	Red-brown clay, with sandy patches	9	—
	Yellow sandy loam	10	—
	Hard brown clay	1	—
	Fine light-coloured sand ...	6	—
	Sandy gravel	12	48
[Reading Beds]	Blue tough clay	2	—
	Red and yellow sandy loam ...	2	—
	Grey loamy sand	8	—
	Green-brown clay	4	64
[Upper] Chalk		32	96

2. Bury (Berry of old map) Green. About 1850.
Made and communicated by G. Ingold.
Shaft 40 ft., the rest bored.
Water 7 or 8 ft., deep in the shaft.

Boulder Clay		20	60 ft.
[Reading Beds]	Yellow sand, from which the water comes	15	
	Brown clay, to Chalk	25	

3. Ford near the river. (? Hadham Ford).
Made and communicated by G. Ingold.
Bored throughout. Water-level 2 ft. down.

Made earth and gravel ...	8	62
Chalk with flints	54	

Hadham, cont.

4. Green Street. South-eastward of the Church. 1883.
Made and communicated by G. Ingold.
Boulder Clay, with slow spring at the bottom, 25 ft.

5. Hadham Hall. East of the Church. 1902.
Communicated by W. Minet.
338 ft. above Ordnance Datum. Water-level 132 ft. down.
Shaft, of 4½ ft. diameter, 100 ft. The rest bored, 7 in. diameter.

		Thickness. Ft.	Depth. Ft.
[Boulder Clay]	Brown clay, with fragments of chalk and shells, much worn ...	12	12
[? Drift or London Clay]	Bluey-grey clay	13	—
	Dark greenish-grey clay ...	6	—
	Brown sandy loam	6	37
[London Clay] ...	Dark grey clay, with traces of lignite	2	—
	Brown sandy loam	2	—
	Grey loam, with iron-pyrites after wood	5	46
[Reading Beds, 43 ft.]	Stiff greenish-brown clay ...	1	—
	Fine dark grey loam	1½	—
	Light-grey and brown loam, slightly mottled	3½	—
	Very tough hard red clay ...	15	—
	Very fine loose grey sand ...	5	
	Green and red mottled sandy loam	6	—
	Compact grey sand	10	—
	Small rounded green-coated flints, passing down into large angular green-coated flints...	1	89
[Upper] Chalk with flints, broken and rubbly for the first few feet, more compact below; beds of hard clunch at intervals in lower part ...		186	275

6. Home Farm. Just west of Hadham Ford
Sunk and communicated by G. Ingold.
255 ft. above Ordnance Datum.
Shaft throughout. Water 3 ft. deep.

White and blue clay	39	
Shingly gravel	7	62 ft.
Brown clay	1	
Chalk...	15	

Another account makes the depth to Chalk 55 ft. and the total 80.

7. Westfield Farm, East of.
From observation, W. H. Penning.

Recent	Sandy wash	3	24 ft., to Chalk.
	Pebble-gravel, in dirty matrix...	11	
Reading Beds.	Loam	10	

8. The following are notes of some other wells.
Also from W. Minet. 1901.

	Above Sea-level. Ft.	Depth to Chalk. Ft.	Total depth. Ft.
Church End, Farm...	285	51	93
Church End House	285	51	93[1]
Little Hadham Place	300	70	106
Rectory	293	59	113
Westland Green. By the northern end ...	361	surface	24

[1] Bored a little deeper.

Hadham, Much.

Ordnance Maps 222, 240, new ser. (Herts. 22, SE.). Geologic Map 47.

1. Barrowfield. Mr. Pasteurs.

Made and communicated by Messrs. A. Williams & Co.

Shaft 5 ft., the rest bored.

Water rose to within 95 ft. of the surface.

		Thickness. Ft.	Depth Ft.
[Glacial Drift]	Ballast [gravel]	5	—
	Red clay	5	—
	Brown clay...	1½	—
	Light-coloured clay	2	—
	Red sand and ballast [gravel] ...	8½	—
	Loamy sand	6½	—
	Black flints with a mixture of gravel, very hard	22½	51
	Brown mottled clay	3	—
[? Reading Beds]	Red mottled clay, with dead sand	10	—
	Red mottled clay	5	—
	Flints	5	74
[Upper] Chalk	... ...	76	150

2. Green Tye, south-eastward of the Church. Public Well. 1879.

Sunk and communicated by G. Ingold.

Shaft 87 ft., bored 2 ft.

A good supply of good water.

[Glacial Drift]	[Boulder Clay]	White and blue Boulder clay ...	54	89 ft.
		Hard brown clay ...	2	
	[Gravel and Sand 32½ ft.]	Red sandy gravel ...	18	
		Red tough sand ...	2½	
		Yellow sandy fine gravel	5½	
		Red sandy gravel ...	6½	
	Brown clay [? London Clay or Drift]		½	

3. Hadham Cross, south of the village. Coffee Tavern.

Made and communicated by G. Ingold.

Bored throughout.

Water-level 25 ft. down.

Clay and stones ...	12	80 ft.
Chalk with flints ...	68	

4. Hill Farm. About a quarter mile E. of S. from the Church. 1903 (?).

Bored and communicated by Messrs. Duke and Ockenden.

Lined 102 ft. with 4½ in. tubes.

Water-level 64 ft. down. Supply good.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift]	Clay and gravel	8	—
	Clay and flints	20	—
	Clay and gravel	4	—
	Sand and gravel	11	43
[Upper] Chalk and flints	... ...	110	153

Hadham, cont.

5. Moor Place, south-westward of the village. 1887.
Shaft throughout.
Water-level about 98½ ft. down, July, 1877; about 98¾, February, 1888.
Communicated by E. E. Berry.

		Thickness. Ft.	Depth. Ft.
Mould		2	2
[Glacial Drift]	[Boulder Clay] Brown clay	10	—
	[Boulder Clay] Blue clay	17	—
	[Boulder Clay] Brown clay	2¼	31¼
	Gravel and clay, concreted	¾	—
	Grey gravel	4	—
	Grey sand	6	—
	Red gravel	8	—
	Grey gravel, with large stones	2	—
	Yellowish-brown clay	6	58
	Soft yellow chalk	12	—
Chalk	White and yellow chalk, harder	3	—
	Hard white chalk, with flints	44	117

6. Nine-acres plantation. 1904.
Made by Messrs. Le Grand and Sutcliff, and communicated to J. C. Thresh.
345 ft. above Ordnance Datum. Well in Chalk, 150 ft. deep.
For an analysis of the water, *see* p. 317.

7. Perry Green, SE. of Hadham Cross.
Good supply of water.

[Glacial Drift]	White Boulder Clay Dark Boulder Clay Sand, etc.	23 ft.

It is a little singular, and might be confusing, that whilst Little Hadham has a Bury (Berry on old map) Green, Much Hadham has a Perry Green.

8. For the Rural District Council. A little south of Bromley (? Bromley Hall Farm) and 1½ miles NW. of the village.
From A. G. Gwynn, Clerk to the Council. 1914.

The Local Government Board Return of 1915 says:—"The average daily quantity of water obtained is 10,300 gallons," and much more could be got. Quality very good.

		Thickness. Ft. In.	Depth. Ft. In.
Soil		1 0	1 0
[Boulder Clay]	Mottled clay and flints	2 0	3 0
[Glacial Gravel]	Gravel	2 4	—
	Coarse ballast [gravel]	2 11	8 3
[Drift? *see* below]	Brown clay	2 3	—
	Blue clay	34 6	—
	Dark grey sandy clay	11 0	—
	Dark grey sandy clay and pebbles.	1 6	57 6
[Reading Beds]	Mottled clay	18 6	—
	Dark tough clay	2 0	—
	Mottled sandy clay	4 6	—
	Sandy clay and pebbles	1 6	—
	Mottled sandy clay	4 6	88 6
	Chalk	223 6	312 0

G. Barrow remarks that, according to the Geologic map the well is at the junction of the Boulder Clay and the underlying gravel and sand. No Reading Beds are shown above the Chalk. The depth to the Chalk would not be expected, judging from the outcrop close by. There may be a sunk hollow. The third and fourth beds from the top he regards as the normal Bunter pebble Drift of the district; the four beds next below as a rather high level local Drift, made up of materials from the Reading Beds; but it is impossible to say where this ends and the Reading Beds begin.

Haileybury, *see* Amwell.

Harpenden.

Ordnance Map 239, new ser. (Herts 27, E.). Geologic Map 46, SE.

1. Brewery. 1876.
Made and communicated by R. B. Paten.
Shaft 58 ft., the rest bored.

Clay and gravel	...	20	(another account says 5)
Chalk and flints	...	180	,, ,, 205
		200	210

2. Kennesbourn Green.
Made and communicated by R. B. Paten.
Shaft 98 ft., the rest bored.

Clay and gravel	... ...	30	250
Chalk and flints	... ...	220	

3. Midland Railway Station.
A. C. G. Cameron's Notes.
Shaft 40 ft., the rest bored.

Chalk	... ...	220 ft.	

4. Ox Lane Nurseries.

Soil	... ...	about 1	
Very gravelly soil	... ...	,, 1	about 10 ft.
Clay with flints	... ...	,, 8	
Chalk.			

Communicated by H. B. Randall.
About 350 ft. above sea-level.
Shaft 39 ft. ? The rest bored.
Water 39 ft. down in winter and at rest, 41 ft. when pumping or in summer.
4,000 gallons an hour pumped.

5. Water Company's Works, Shakespeare Road.
Communicated by W. R. Phillips.

		Ft.
Brickearth	... ...	1½
Chalk	... ...	130

According to the Local Government Board Return of 1915, p. 195, "Three wells with boreholes . . . The average daily quantity of water obtained is 138,000 gallons," and more can be got: "the water is excellent."

For an analysis of the water, *see* p. 318.

Hatfield.

Ordnance Map 239, new ser. (Herts. 35, E.). Geologic Maps 7 and 46, SE.

1. Astwick Manor (Astwick Farm, of the old map, 2 miles WNW. of the town).
1888.
Bored and communicated by Messrs. Le Grand and Sutcliff.
Water-level 25 ft. down.

		Thickness. Ft.	Depth. Ft.
Surface ground	... ...	4	4
[Glacial Drift] ...	Gravel	4	—
	Blue clay and stones	11	—
	Gravel	5	—
	Blue clay	15	—
	Gravel	2	—
	Yellow clay	3	—
	Red sand	5	—
	Gravel and large stones ...	2	51
Chalk	Chalk marl [soft chalk] ...	2	—
	Chalk and flints	30	83

Hatfield, cont.

2. Ponsbourne Park, 4½ miles ESE. of the town. 1876.
Sunk and communicated by R. B. Paten.
Shaft 10 ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
	Clay and stones [? Boulder Clay]	8	—
[Drift, 20 ft.] ...	Red sand	2	—
	Gravel	10	20
[London Clay, 140 ft.]	Blue clay	106	—
	Sand and clay	34	160
[Reading Beds, 31½ ft.]	Light-coloured sand	6	—
	Sand and pebbles	3½	—
	Light-coloured sand	11	—
	Sand and pebbles	2	—
	Sand	8	—
	Flints	1	191½
To Chalk.			

3. Railway Station.

Messrs. Le Grand and Sutcliff say that a well was sunk to the depth of 105 ft., with headings, and then a boring made to the depth of 420 ft., without getting an adequate supply. A bed of chalky sand was met with at the depth of 365 ft., from which it is thought that the water came.

According to another account the depth to the chalk (through gravel) was about 40 ft., and the water-level about 30 ft. down.

4. Warrenwood. Over 2 miles south-eastward of Hatfield House.
370 ft. above Ordnance Datum.
Made and communicated by Messrs. A. Williams and Co.
Well 10 ft., the rest bored.
Water rose to within 210 ft. of the surface.

		Thickness. Ft.	Depth. Ft.
	Mottled clay	10	—
[Glacial Drift] ...	Red sand and stones	13	—
	Coarse ballast [gravel]	4	27
	Brown clay	3	—
[London Clay, 118 ft.]	Blue clay	114	—
	Black pebbles	1	145
[Reading Beds, 30 ft.]	Green sands	12	—
	Mud and pebbles	4	—
	Green sands	10	—
	Mixture of marl	4	175
[Upper] Chalk and flints		175	350

5. Waterworks. For the Marquis of Salisbury.
Made and communicated by Messrs. Isler and Co.
90 ft. of 15½ in. tubes from 15 ft. down.
Water-level 156 ft. 8 in. down.

		Thickness. Ft.	Depth. Ft.
	Ballast [gravel]	16	—
[Glacial Drift] ...	Yellow sand	2	—
	Rough ballast [coarse gravel]...	25	—
	Gravel and clay	5	48
[Upper] Chalk and flints		256	304

Other accounts vary. One dates the work 1891, gives the depth of the shaft as 14 ft. and makes the depth to the Chalk 30 ft. (through mottled clay and gravel). Yet another makes it 32 ft. (through gravel) and gives the yield as 7,400 gallons an hour. The difference in the accounts may be explained by the fact that there are two borings.

According to the Local Government Board Return of 1915, p. 279, the Marquis of Salisbury "supplies parts of parishes of Bishop's Hatfield . . . and St. Peter Rural (St. Albans R.D.)." by two "wells in Chalk, at Hatfield. The average daily quantity of water derived from each" is 90,680 and 82,780 gallons, or a total of 173,460. Quality satisfactory.

For analysis, *see* p. 319.

Hemel Hempstead.

Ordnance Map 238, new ser. (Herts. 33, E.). Geologic Map 7.

1. Boxmoor. London and North Western Railway.

Made and communicated by R. Paten.

Yellow clay and stones	6	91 ft.	
Chalk	85		

2. Highfield. NE. of the Railway Station.

Made and communicated by R. B. Paten.

Shaft 200 ft., the rest bored.

Clay and gravel	45	396 ft.	
Chalk and flints	351		

3. Pouchen End House. About two miles WSW. of the church.

About 400 ft. above Ordnance Datum.

Bored and communicated by Messrs. Isler and Co.

Water-level 112 ft. down. Supply good.

Dug well (? old) the rest bored	114	174 ft.	
Chalk	60		

At Mr. Cooper's house, Pelden, southward from the railway-station, some very hard chalk was found 323 ft. down, by Messrs. Cheeld and Co. in 1911. It ended at 330 ft., and the boring was stopped at 340.

4. Waterworks. In the town, on the western side of Marlowes and north of Bath Street. A boring of 1868, at the western side of the engine-house, is said to be 182 ft. deep.

Boring of 1909. Communicated by W. R. Locke, Engineer.

Very hard chalk, about 266 and 273 ft. down. Also below 282 ft.

Very tough chalk, with water ? at 286 ft.

Soft white chalk at 291 ft.

Soft chalk below 293 ft., and at 330.

Bottom of white chalk at 325 ft.

On 21st May (? about 170 ft. down) when pumping about 26,000 gallons an hour from No. 2 boring, the water was lowered a foot in new (No. 3) boring.

On 2nd July (at the depth of 320 ft., or more) pumping 20,000 gallons an hour, in the new bore, lowered the water-level 9 ft.

On 14th July (at the depth of 344 ft. or more) pumping 23,300 gallons an hour lowered the water-level 5 ft. 4 in.

On 15th July, rest-levels before grouting the space between 24-in. and 18-in. tubes, 3 ft. down inside the 18-in. tubes, 4 ft. 8 in. between the two tubes.

There are 100 ft. of 18-in. and 50 of 24-in. tubes.

The Local Government Board Return of 1915, p. 61 says:—"Borings, 300 to 400 ft., in Chalk. The average daily quantity of water obtained is 260,000 gallons." Quality very satisfactory (For analysis, *see* p. 319). Supplies also parts of the parishes of St. Michael Rural (St. Albans Rural District) and Abbots Langley.

5. The water-levels at three other wells in Hemel Hempstead are given in *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 578.

6. There are borings in the watercress-bed north-westward of the waterworks to the depth of 100 ft. ? The nearer could not be seen when I was there in July, 1907, but the further one had water flowing strongly from it. I understood that various observers had seen the reverse taking place, that is, water from the watercress-beds running down a bore-hole, which, of course, must have been in a very dry season, when the underground water-level is lower than usual.

Hertford.

Ordnance Map 239 new ser. (Herts. 29, S). Geologic Maps 46, SE., 47.

1. Fanshaws, Brickendon. Nearly 3 miles southward of the town (Herts. 36, NE.)

Made and communicated by J. A. HUNT, of Hoddesdon.

About 310½ ft. above Ordnance Datum.

Shaft 167 ft., cylinders about 20 ft. more, the rest bored.

Water-level about 178 ft. down.

		Thickness. Ft.	Depth. Ft.
Drift		6	6
[London Clay, 152 ft].	Blue clay	145	—
	Sandy clay. Shell-bed [basement-bed]	7	158
[Reading Beds, 32 ft.].	Grey sands and clay ...	17	—
	Loamy sands	10	—
	Sand and pebble-bed ...	5	190
[Upper] Chalk		129	319

2. Messrs. Gripper's Malting.

Made and communicated by Messrs. ISLER and Co. 1901.

Made ground	9½	16¾ ft.
Ballast [River Gravel]	6¾	

3–6. Waterworks (established 1862). Four Pumping Stations.

Information from A. F. HOLDEN, Borough Engineer; from the Local Government Return of 1915, &c.

Daily average supply 275,000 gallons. Quality good.

3. Port Hill Pumping Station. By the left side of the Beane, a little north-north-west of the Great Northern Railway Station. The first made?

A stand by. Could yield 300,000 gallons a day.

No information [gravel]	12	172 ft.
[Upper] Chalk and flints	160	

4. Hartham Pumping Station. By the side of the stream a little eastward of the Great Northern Railway Station. 1884.

Average daily yield 60,000 gallons (1915).

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

Filled in ground		4	81 ft.
[River] Gravel		12	
[Upper Chalk]	Soft chalk and flints ...	38	
	Hard chalk and flints ...	27	

5. Molewood Pumping Station. At Molewood Mill, on the left (eastern) side of the Beane. 1888.

Average daily yield 190,000 gallons.

Gravel and flints	6	100 ft.
[Upper] Chalk and flints	94	

6. Waterford Pumping Station. On the left (eastern) side of the Beane west-north-west of Waterford House. 1900.

Average daily yield 25,000 gallons.

Filled in ground		2	115 ft.
[?River Drift]	Ballast, sand and gravel ...	13	
	Red gravel	11½	
[Upper] Chalk and flints		88½	

7. Dr. R. L. SHERLOCK notes that a well about 400 yards north-westward of the station, on the new Great Northern line, is about 90 ft. deep, with from 20 to 30 ft. of gravel over Chalk, yielding water in good quantity at the bottom.

Hertford, cont.

8. Clements Farm, Brickendon. 1902 ?
Communicated by Dr. R. L. Sherlock.
Well of $4\frac{1}{4}$ ft. diameter.
Water-level, 6th February, 1904, $17\frac{3}{4}$ ft. in the well (highest), and remained 16 ft. for some time.

Soil	1		
Glacial Drift { Chalky (Boulder) Clay	41	$127\frac{3}{4}$ ft.	
Glacial Drift { Clean sharp sand	$30\frac{1}{4}$		
Upper Chalk	$55\frac{1}{2}$		

Hertingfordbury.

Ordnance Map 239, new ser. (Herts. 29, SW.). Geologic Map 46, SE.

A. C. G. Cameron notes that two wells close to Cole Green Railway Station are 24 ft. deep in gravel. These may be those which Dr. R. L. Sherlock describes as Pump at the western corner of the Green, and house on the Green, at both of which water is said to have risen to the surface.

From the same observer we learn that a well 200 yards west-south-west of the Church, 61 ft. deep (? 30 ft. through gravel to Chalk) has very little water, and that another, 600 yards west of the church, 80 ft. deep (Chalk reached about half way down) has 4 ft. of water.

According to the Local Government Board Return of 1915, p. 278, Lord Desborough "Supplies part of parish of Hertingfordbury" from a "Well near River Mimram, Panshanger Park."

High or Chipping Barnet, *see* Barnet.

Hinxworth.

Ordnance Map 204, new ser. (Herts. 23, NE.). Geologic Map 46, NE.

The Schools. North-west of the Church.
Made and communicated by J. Conder, of Baldock.

Shaft 53 ft., the rest bored.

Gravelly soil	3	183 ft.
Blue clay (Gault) to sand	130	

All the wells in Hinxworth and at the coprolite-pits (now abandoned) between there and Astwick are about the same depth, not varying more than 5 ft., and always finding water in sand below the Gault.

The Rev. J. C. Clutterbuck has said of the water of one of these wells that it is "particularly soft, clear, and of good flavour," but "if not used as quickly as under ordinary circumstances, it becomes a little cloudy." Prestwich's Water-bearing Strata, 1851, p. 167.

Hitchin.

Ordnance Map 221, new ser. (Herts. 12, NW.). Geologic Map 46, NE.

1. Brewery, in the town, between the Priory and the Church. 1831.
Communicated by Mr. Lucas.
About 220 ft. above Ordnance Datum.

		Thickness. Ft.	Depth. Ft.
Made ground		3	3
[Drift, 77 ft.]	Layer of pebbles	1	—
	White marl	$1\frac{1}{2}$	—
	Green sand[1]	$6\frac{1}{2}$	—
	Green sand[1]	10	—
	Fine green sand[1]	32	—
	Coarse green sand[1] ...	3	—
	Green sand[1]	23	86
	Whitish marl	43	—
[Chalk and Chalk Marl ?]	Light-coloured clay ...	$74\frac{1}{2}$	—
	" " " ...	24	—
	" " " ...	$7\frac{1}{2}$	229

[1] [The green colour of these beds may have been owing to the specimens being wet.]

Hitchin, cont.

		Thickness. Ft.	Depth. Ft.
	Strong blue clay	101	—
	Strong clay	5	—
[Gault, 214 ft.]	Clay	105	—
	Crumbling clay with stones and gravel [?phosphatic nodules]	3	443
	Olive-coloured sand ...	8	—
[Lower Greensand, 23 ft.]	White sand, into which pipes entered	5½	—
	White sand, into which pipes could not pierce ...	9½	466

I have left the classification as originally given, when deep channels of Drift had not been noted in these parts and practically no divisions in the Chalk had been established. In writing on the subject of Drift channels W. Hill says that this boring "must have been commenced just below the Melbourn Rock. As there is not more than 170 feet of Lower Chalk in this locality, Gault should have been reached at that depth. . . I am inclined to think . . . that much of the white and grey marl . . . may be Drift." *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv, p. 17.

2. Charlton, south-west of the town. New cottages near the windmill.

Information got by A. J. Jukes-Browne.

Dug 60 ft. through chalk, with one band of flints, into a hard rock, from which water rises [Melbourn Rock, from which springs rise at Charlton.]

3. Foxholes (Mount Pleasant of old map). Westward of the town.

W. Hill, *Quart. Journ. Geol Soc.*, 1905, vol. lxiv, p. 16.

Boulder Clay and gravel, without reaching water or Chalk, 100 ft., although Chalk crops out close by. A trial then made some 25 or 30 yards nearer the outcrop, found Chalk close to the surface.

Presumably the following note from W. Hill (September, 1914) refers to this well. It describes a boring at the SE. corner of Mount Pleasant, which gave the following section :—

Soil	2	
Red clayey sand	10	
Rather sharp grey sand, with some chalk ...	14	166 ft.
Yellowish-grey clay, seemed to pass into the next	10	
Grey Boulder Clay, with small chalk lumps: few boulders	130	

4. Highover Farm, north-east of the town, near the barn.

Information given to Mr. Jukes-Browne by the foreman.

Dug through clay and loam	8	16 ft.
„ gravel to water	8	

The same water-bearing gravel is intersected in the railway-cutting, into which water often runs. Another well was sunk in a field half a mile due east of the farm, and water found in similar gravel, below clay, about 40 yards from the road leading to Willbury Hill. A. J. J.-B.

5. Queen Street. Steam Laundry. 1912.

W. Hill, *Proc. Geol Assoc.*, 1912, vol. xxiii, p. 222.

[Glacial Drift.] Sandy gravel and small stones, passing down into sand, with a thin bed of greasy clay at 62 ft. deep. 125 ft., and Chalk not reached.

6. Mr. T. Ransom's Brickyard, Bethel Lane. About 200 yards east of the London Road at the southern outskirts of the town, a mile SW. of the Railway Station.

W. Hill, *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv, pp. 16, 17.

Also from Messrs. Le Grand and Sutcliff, who made the boring.

275 ft. above Ordnance Datum.

Commenced with a four-inch pipe, then a three-inch pipe, which it was difficult to drive.

No water got.

Hitchin, cont.

		Thickness. Ft.	Depth. Ft.
Old well (mostly brick-earth)		—	64
Glacial Drift ...	Loamy ballast [gravel] ...	3	—
	Live blue sand	20	—
	Sandy clay and stones	3	—
	Sandy ballast [gravel]	36½	—
	Sandy clay	3	—
	Clay, stones, and small pieces of chalk	6½	—
	Stiff clay	5	—
	Sandy clay and sand	7	—
	Sand	16	164
	Stiff clay and stones. Some lignite at 169–177 ft. down ...	32	196
	Clayey sand	10	—
	Clay and stones	4	—
	Very hard sand	7	—
	Live sand	29½	—
	Sand and stones	26½	—
	Stony clay	21½	—
	Blowing sand	4	—
	Stony clay	14½	—
	Clayey sand, stones, and small pieces of chalk	4	—
	Blue sandy clay...	15	—
	Sandy clay and stones	8	340
Gault. Stiff dark blue clay		5	345

Mr. HILL was present when the auger brought up Gault, which he thought was not from the top part of the formation.

This boring clearly proves the occurrence of a deep channel of Drift: so deep that here the Chalk has been cut through.

7. At the northern end of the town, ¾ mile NNW. of Ransom's boring.

W. HILL, *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 18.

An old well, of which details are lost. It has been filled in.

About 209 ft. above Ordnance Datum.

Sunk about 90 ft. in blue clay; but enough water not being got, a boring was made to about 90 ft. more, and still no water was got.

This shows a great thickness of Boulder Clay, etc.

"A fairly strong spring is thrown out by the Chalk 800 yds. to the north-east, and it seems certain that if that rock had been reached, water would have been found."

8. Waterworks. Established 1854. At the south-western corner of Priory Park. The old well, just north of the Bath Spring (a well about 6 ft. deep) is itself only about 16 ft. deep.

The following figures are from observations made in April, 1907, by W. R. PHILLIPS, Engineer, of Luton.

Wellhead Spring.	Water-level	235·97 ft.	above Ordnance Datum.
Bath Spring.	,,	223·2	,, ,,
Waterworks Well.	,,	222·36	,, ,,
River Hiz (just NW.)	,,	219·48	,, ,,

In the second case the water would rise about a foot, if no water were taken. Presumably, however, this would be accompanied by a slight rise in the Bath Spring, not 30 yards off.

For an analysis of the water, *see* p. 320.

9. Waterworks. Newer well. At the north-western corner of field 56, 120 ft. from the hedge on the north and 100 from that on west. About 340 yards SSW. from the old well? 1907.

Journal of the work, from JOHN DAVEY, Engineer.

Two trenches were made in the field, 30 ft. from the western hedge, each 5 ft. wide, 40 ft. long, and 6 ft. deep. The rest-level of the water in these was about a foot below the water in the lake (on the other side of the track). No water came in on the lake-side of the trenches.

Hitchin, cont.

Then the well was made, near the trenches.

Oct. 29. Loose chalk, lumpy, to 9 ft. down.

Oct. 30. Chalk in large lumps, with fine chalk between to 11¼ ft. down. When work was stopped at night water rose at the rate of 3 in. a minute.

Oct. 31. Chalk, lumps increasing in size on N. to 14¾ ft. When work was stopped at night, the flow into the well was 4½ in. a minute.

Nov. 1. Chalk, with occasional lumps of Melbourn Rock to 17¼ ft. When work was stopped at night, the flow into the well was 5½ in. a minute.

Nov. 2. Chalk, with a bed of Melbourn Rock, and detached lumps, to 19 ft. When work was stopped the well filled up at the rate of 6 in. a minute.

All the way down nine-tenths of the water came in from the east, north and west, very little on the south.

Below this is softer chalk, with lumps of the Rock.

A later communication says that the well was taken to the depth of 27 ft., about 3 ft. below Melbourn Rock, into softish marl (Belemnite Marl), and that then a 12-in. boring was made on the northern side of the well with a tube 5 ft. down and 2 above the bottom of the well. Very little water was got from this, the chalk being very soft, until they got down 20 ft.; at about 30 ft. down [in the boring] a large increase was got; and at about 35 ft. the water flowed over the top of the tube, at the rate of about 100,000 gallons in 24 hours.

The boring was continued for another 8 ft., in very soft chalk, and all the chalk that was broken up was washed up over the tube, no shelling being needed.

After pumping night and day for a fortnight, Mr. Davey calculated that between 700,000 and 800,000 gallons a day were got, the water standing about 3 to 4 ft. in the well.

A letter from W. Hill (3rd November, 1907), when the well must have been about 20 ft. deep, says that the rest-level of the water was 1 to 2 ft. below that of the mill-head (northward) and about 2½ below that of Wellhead spring (southward). When the well was 12 ft. deep a pulsometer was throwing out water at the rate of 200,000 gallons a day, and at the depth of 16 ft. this rose, according to Davey's measurements, to 400,000.

The material passed through was gravelly soil, 4 to 5 ft., and then chalk-rubble. If the Melbourn Rock goes to some depth down, as seems to be the case, the line for it on the map is too high; but as the rock is shown at Wellhead spring, there may be a small fault between this and the well.

According to the Local Government Board Return of 1915, p. 65, "The average daily quantity of water obtained is 260,000 gallons," and much more could be got. The water is excellent. Supplies parts of Ippollitts and Walsworth.

In 1893 a number of borings were made to test the order of certain Drift-beds at Hitchin. These have been described in detail by C. Reid, and readers are referred to his paper, in *Proc. R. Soc.* 1897, vol. lxi, pp. 40-49.

Hoddesdon.

Ordnance Map 239, new ser. (Herts. 37, NW.). Geologic Maps 1, SW and 47.

1. Brewery.

Prestwich, *Quart. Journ. Geol. Soc.*, vol. x, p. 146.

		Thickness. Ft.	Depth. Ft.
[River] Gravel	... ...	20	20
London Clay and Reading Beds.	Loam and marly sand ...	45	—
	White sand	24	—
	Flints	1	90
Chalk ...	... ...	4	94

2. Pumping Station of the Metropolitan Water Board, by the side of the New River, nearly a third of a mile east of St. Catherine's Church. 1868. Sunk and communicated by Messrs. T. Docwra and Son.

About 103 ft. above Ordnance Datum.

Shaft 52 (or 54 ?) ft. the rest bored. Water rose to 2 ft. below the surface. Yield 2,160,000 gallons a day. J. M. Wood states (in 1920) that the standing water-level does not vary, being 102·45 ft. above Ordnance Datum, where it has stood for years; and that the yield, which is practically permanent, is 2,250,000 gallons a day.

Hoddesdon, cont.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
[River Drift], 23½ ft.	Brown sandy clay ...	3½	—
	Sand and gravel [bottom irregular] ... about	20	24½
	Chalk ... ... about	19½	—
	Chalk, with two thick beds of flints [? others] ...	32	—
	Soft place (rod sunk) ...	1½	77½
	Chalk	58	—
[Upper Chalk], 261½ ft.	Chalk with scattered flints	38	—
	Chalk, with flints (the higher part soft)	8	—
	Blackish chalk	1	182½
	Soft chalk and flints ...	90	—
	Yellowish rock-chalk ...	3½	—
	Hard chalk, flints at bottom	2	—
	Soft chalk	8	286

The boring has been continued to 403 ft.

3. For the New River Company.

Made and communicated by Messrs. Docwra.

(Clark's.) Water overflowed.

		Thickness. Ft.	Depth. Ft.
Soil		1	1
	Brown clay	1	2
[Alluvium, 4 ft.]	Brown clay and sand ...	2	4
	Peat and stones	1	5
Gravel		19	24
Sand, to Chalk		13	37

4. Waterworks (about 600 yards west of north from St. Catherine's Church).

Made and communicated by Messrs. Docwra.

Cylinders to 95 ft., the rest bored.

		Thickness. Ft.	Depth. Ft.
[? River Drift]	Loam	1½	—
	Gravel	12½	14
[? Reading Beds.]	White sand	3	—
	Yellow loamy sand ...	15 or 15¾	—
	Flints	? 1¼	33 or 34
Chalk, with flints at 85 ft.		? 177 or 176	210

Holwell.

Ordnance Map 221, new ser. (Herts. 7, SW.). Geologic Map 46, NE.

Holwell Bury, despite its name, is not in this parish, but just over the border in the Bedfordshire parish of Upper Stondon. The well here is duly noticed in the Memoir on the Water Supply of Bedfordshire, but under Holwell (p. 49), though that is a Hertfordshire parish. It is indexed under Stondon, though that name does not appear. *See also* W. Hill, *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv, p. 19.

Hunsdon.

Ordnance Map 240, new ser. (Herts. 30, S.) Geologic Map 47.

1. Briggins Park, southward of the Church. 1897. Last 50 ft. in 1905.
Made and communicated by Messrs. Isler and Co.

100 ft. of 4-in. tubes from 4 ft. down.
Water-level 64 ft. 3 in. down (1895).
Yield 480 gallons an hour (1895).

Hunsdon, cont.

		Thickness. Ft.	Depth. Ft.
Dug well (the rest bored)		—	67
[Reading Beds]	Grey sand	11	—
	Grey sand and pebbles ...	9½	87½
[Upper Chalk]	Chalk and flints	7½	—
	Chalk	162	257

The well (? old) must be through London Clay and Reading Beds.

2. Hunsdon Bury. 1882.

Made and communicated by Messrs. Docwra.

Shaft 56 ft., the rest bored.

Water-level 106 ft. down.

		Thickness. Ft.	Depth. Ft.
Undescribed		28½	28½
[Drift]. ...	Blue clay	10½	—
	Sand	9	—
	Gravel	1	—
	Blue clay	7	—
	Sand	15	—
	Gravel	2½	—
	Loamy sand	1½	—
	Dark Sand	4½	79½
Reading Beds.	Coloured [mottled] clay ...	15½	—
	Sand	1½	—
	Coloured [mottled] clay ...	8½	—
	Light [-coloured] sand ...	10	—
	Green sand	7	—
	Flints	½	122½
Chalk		59½	182

3. The Turkey Coc[illegible] Inn. 1900 ?

Bored and communicated by Messrs. Merryweather.

Water-level 89¾ ft. down.

		Depth. Ft.	Thickness. Ft.
Mould		2	2
Gravel		2½	—
[Boulder Clay.	Yellow clay and flints ...	10½	—
	Black „ „ ...	20½	35¼
[Glacial Gravel.]	Gravel and flints	2¼	—
	Red sand	10½	—
	Rough gravel, large stones	6½	54½
[London Clay, 24¾ ft.]	Dark clay	13¼	—
	Grey clay and sand ...	10¾	—
	Fine grey sand with water	¾	79
	Red, green and blue mottled clay	21½	—
[Reading Beds, 47 ft.]	Green and brown mottled sand	9	—
	Green sand	6½	—
	Grey loamy sand	5	—
	Black „	2	—
	Fine grey sand with water	1	—
	Black clay with flints ...	2	126
Upper] Chalk		71	197

Ickleford.

Ordnance Map 221, new ser. (Herts. 7, SW.) Geologic Map 46, NE.

Rectory. In the garden. 1906.

Made and communicated by Messrs. Le Grand and Sutcliff.

Mostly published by W. Hill, *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv, p. 18.

180 ft. above Ordnance Datum.

Water-level 11 ft. down. W. Hill wrote that the water was so impregnated with iron, that it was thought unfit for household-purposes.

	Thickness. Ft.	Depth. Ft.
Soil or mould	2	2
Clay and stones	15	17
Sand and gravel	12	29
Sand and thin veins of clay	10	39
Sandy clay	11	50
Boulder Clay, with pieces of chalk, flints, etc. A thin layer of flints at 75 ft., with water... ...	66	116
Boulder Clay, with grains of chalk diminishing in number	30	146

W. Hill says "I have seen the sample from 146 ft.; I am not quite satisfied that it is Gault, but it may be."

He writes that the water-bearing bed at 75 ft. seems to have a wide extension; and that he has seen it at cottages near Ramerick, and Ramerick Farm well is in it. The water-levels are the same.

A more recent boring, only 90 yards NE., showed Chalk almost at the surface, the "Cambridge Greensand," with phosphatic nodules, occurring at the depth of 135 ft. W. Hill, *Proc. Geol. Assoc.*, 1912, vol. xxiii, p. 223.

Ippollitts

Ordnance Map 221, new ser. (Herts 12, W.) Geologic Maps 46, NE., SE.

1. Gosmore. About 300 yards NNW. of Thistley Farm, westward of the village 1912.

W. Hill, *Proc. Geol. Assoc.*, 1912, vol. xxiii, p. 221.

A boring, about 280 ft. above Ordnance Datum. ? Made by C. P. Martin of Harpenden.

		Thickness. Ft.	Depth. Ft.
Glacial Drift ...	Gravel and sandy clay ...	20	20
	Fine white sand, free from chalky matter	2	22
	Soft brown sand	15	37
	Gravel and sandy clay ...	16	53
	Running sand (water)	10	63
	Blue chalky Boulder Clay ...	12	75
	Loose sand and shingle ...	3	78
	Very hard pebbly rock ...	5	83
	Brown clayey sand, with minute rounded chalk-grains, angular pieces of flint, etc.	117	200

The boring was then stopped, Chalk not having been reached.

2. Gosmore. Another boring, about 660 yards NNW. of Thistley Farm. 1917.

Sir A. Strahan. *Mem. Geol. Survey. Summary of Progress* for 1917, pp. 46, 47. (1918.)

Sunk and communicated by Messrs. Le Grand and Sutcliff.

And Summary for 1918, p. 65.

270 ft. above Ordnance Datum.

No water got from the lower part, but a supply enough for the farm got from gravel at 70–97 ft.

Ippollitts, cont.

		Thickness. Ft.	Depth. Ft.
Dug well (the rest bored)		—	44
Glacial Drift ...	Drift, clay and stones	16	60
	Flints and large stones, water-level varies	20	80
	Gravel and sand	6	86
	Sand	11	97
	Clay with grains of chalk ...	29	126
	Hard rock	8	134
	Sandy clay	6	140
	Sand and flints	12	152
	Sand, clay and stones	34	186
	Sand and veins of chalk ...	12	198
	Grey clay or chalk	20½	218½
	Clay, sand and stones	1½	220
	Clay, light-blue (specimen, pale-bluish-grey silty clay, free from large grains)	to 30	250

Sir A. STRAHAN adds (in the Summary for 1917) that "the base of the Chalk might have been expected at a depth of 210 ft. . . . If the estimate of the position of the base of the chalk is correct, the bottom . . . must be 36 ft. [? 40] below that base. No chalk in place has been traversed in the boring, but the clay at 220–246½ ft. [? 250] might be Gault, though its appearance is more that of a stoneless band in boulder-clay."

"The boring is situated near the western margin of the drift-filled channel described by W. Hill in the *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 8." *See* Hitchin wells, pp. 223-225.

In the Summary for 1918, Sir A. STRAHAN says "A comparison of the two records shows that the drifts passed through differ in detail; the beds of sand, gravel and boulder-clay are clearly liable to variation. The earlier boring failed to find water."

3. Poyters End. East of Preston.

Made by C. P. MARTIN of Harpenden.

		Thickness. Ft.	Depth. Ft.
[? Glacial Drift]	Clay and flints	20	20
	Chalk and clay mixed	50	70
	Chalk	30	100
	Chalk rock	4	104
	Chalk	53	157
[? Middle and ? Lower Chalk]	Chalk and clay (very exceptional)	2	159
	Chalk	98	257
	Tough chalk	95	352
	Very open chalk	5	357
	Medium open chalk	25	382

Kelshall.

Ordnance Map 221, new ser. (Herts. 4, SE., 8, NE.) Geologic Map 47.

Draft Report of Special Committee of Ashwell Rural District Council, Nov., 1913. Communicated by the Local Government Board.

There is "an unfailing well in the Boulder Clay on the Middle Farm" and "a deep well into the Lower Chalk dug 250 ft. with a bore 150 ft. . . . at a dairy farm."

Kings Langley.

Ordnance Map 238, new ser. (Herts. 38, NE.). Geologic Map 7.

Apsley Mill. About 1¾ miles NXW. of the Church. Communicated by S. C. HOMERSHAM.

242 ft. above Trinity Highwater Mark.

Shaft about 16 ft., the rest bored.

Kings Langley, cont.

Water-level about 8 ft. down. Supply 260,000 gallons a day.

? Alluvial earth &c.	about 16	221 ft.
Chalk with 6 layers of flints	„ 97	
Chalk	„ 108	

Home Park Mill. (SE. of the church) communicated by S. C. HOMERSHAM, 1843.

215 ft. above Trinity Highwater Mark.

Shaft 36 ft., the rest bored.

Water-level about 9 ft. down. Supply 473,000 gallons a day.

[River] Gravel	about 9	232 ft.
Chalk with 7 layers of flints...	„ 77	
Chalk	„ 146	

London and North Western Railway Station.

Made and communicated by R. PATEN.

Yellow clay and stones	9	91 ft.
Chalk...	82	

Shendish. North-westward of the village, 1875.

About 443 ft. above Ordnance Datum.

Sunk and communicated by R. B. PATEN.

Shaft 120 ft., the rest bored. Chalk, 450 ft.

There must be Clay with flints at top.

Knebworth.

Ordnance Map 221, new ser. (Herts. 20, E.). Geologic Map 46, SE.

1, 2. For the Great Northern Railway Co. East of the line, south of Roaring Meg Plantation.

1. A 4-in boring, made by Messrs. LE GRAND and SUTCLIFF. Begun 16th September, 1912.

Gravel water-level 14 ft. down. Chalk water-level 15½ ft. down. The water in the gravel not in large quantity.

Yield, 720 gallons an hour on a short trial.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift]	Fine gravel	3½	70 ft. to Chalk and flints.
	Bed of flints	3	
	Loamy gravel		
	Coarse loamy gravel with water	14½	
	Brown clay	1	
	Blue sandy clay	19½	
	Stiff brown clay	7½	
	Blue clay	4	
	Gravel 5 ft., a few inches of soft sandy clay at 58 ft.	17	

For analysis of the water, *see* pp. 321, 322.

2. Well. Made by Messrs. SANGWIN and Co. Begun 30th November, 1912. 262·9 ft. above Ordnance Datum.

Water-level 12¾ ft. down.

At 57 ft. (reached 20th February, 1913) running sand boiled up 6½ ft. into the well and the work was stopped for a time.

Pumping sand and water, from below 57 ft., at the rate of 10,000 gallons an hour, was probably answerable for the caving in of the top part on and after 15th June, and the consequent filling up of the well to 25 ft. from the surface. Piles were driven down on the side of the well. The depth of the sand having been found, by means of a 5-inch boring a few ft. away, cylinders, of 6 ft. diameter, were put down the well, to the depth of 81 ft. 7 in. In the following section the beds below 57 ft. are described from the trial-boring, close by. The well was stopped at 83 ft.

Knebworth, cont.

		Thickness. Ft.	Depth. Ft.
	Sand and fine gravel ...	15½	—
	Coarser gravel	6½	—
	Soft brown clay	1	—
	Blue clay	14	—
[Glacial Drift]	Silt	6	—
	Brown clay	14	—
	Fine running sand ...	7	—
	Ballast [gravel] and small chalk	9	73
[Chalk.]	Soft putty-chalk	2	—
	Firmer chalk	15	90

3. Waterworks. By the road-side just south of the rectory.

About 400 ft. above Ordnance Datum.

Information from W. Wilson, agent to the Earl of Lytton, to whom the works belong.

Shaft 190 ft, the rest bored, 6 in. in diameter. Two headings, one 123 ft. long, the other 100.

Clay and stone	15	400 ft.
[Upper and Middle] Chalk	385	

The Chalk Rock was passed through near the bottom of the well.

Standing water-level 160 ft. down. Pumping level 18 ft. lower.

Minimum yield 36,000 gallons an hour. Average yield 50,000. Could be increased by 70,000. G. Barrow remarks that the total of 120,000 gallons is poor for such large surfaces, and confirms the evidence from Codicote that the Chalk does not yield fully here.

Presumably the amount is ample for the purposes of the place. The works supply the park, village, railway-station, farms, etc. Also part of Welwyn.

Quality of water excellent.

Langley.

Ordnance Map 221, new ser. (Herts. 20, N.). Geologic Map, 46, SE.

1. Dye's Farm. About half a mile northward of the village.

W. Hill. *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv, p. 13.

302 ft. above Ordnance Datum.

A shallow well deepened in 1905? to 64 ft., then bored.

		Thickness. Ft.	Depth. Ft.
	Original well. Soil, red loam	—	24
[Glacial Drift]	Sand and ballast [gravel]...	18	42
	[Boulder Clay] Blue clay with chalk lumps ...	36	78
[Middle] Chalk.	Plenty of water as soon as it was touched	2	80

2. House on the eastern side of the high road. About half a mile north-westward of the village.

W. Hill. *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 13.

[Glacial Drift]	Sand and gravel ... about	75	about 80 ft.
[Middle] Chalk	... ...	5	

3. Meadow east of the London road (200 yards from it), three-quarters of a mile north-westward of Dye's Farm?

W. Hill. *Quart. Journ. Geol. Soc.*, vol. lxiv, pp. 13, 14.

Made and communicated by Messrs. Cheeld, of Chesham.

Just under 300 ft. above Ordnance Datum (estimated).

Fine gravel, passing down into sand. At 83 ft. down 18 in. of clay, and below that several layers of clay. Carried down into blowing sand, which choked the borehole. Some water occurred, but the boring was abandoned at 100 ft.

Langley, cont.

4. For proposed Isolation Hospital (Hitchin Joint Hospital Board.)

About 300 yards west of the London road, almost opposite the third milestone from Hitchin.

W. Hill. *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 14.

Made and communicated by Messrs. Le Grand and Sutcliff.

About 318 ft. above Ordnance Datum.

Water-level 56½ ft. down. Yield about 600 gallons an hour.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift]	Clay and flints	76	76
	Brown loamy sand ...	9	85
	Blue clay and flints ...	29	114
	Brown blowing sand ...	19	133
	Sand and gravel	21	154
	Coloured clay	5	159
[? Middle Chalk]	Rubbly chalk and flints ...	13	—
	Chalk and flints	28	200

The blowing sand at 114 and 133 ft. is probably the same bed as that found in No. 3.

These four sections all point to the occurrence of a channel filled with Drift, and one of which no sign is given by geologic mapping. The Boulder Clay in No. 1 does not come to the surface; but it looks possible that the top bed in No. 4 may belong to this division of the Drift.

Langley, *see* Abbot's and King's.

Letchworth.

Ordnance Map 221, new ser. (Herts. 7, S.). Geologic Map 46, NE.

Garden City Waterworks.

About 300 ft. above Ordnance Datum.

Letter from Col. L. S. Bowring.

Water-level 87 ft. down, reduced but slightly after several hours pumping, and rapidly rises on cessation of pumping.

		Thickness. Ft.	Depth. Ft.
[Boulder] Clay	... ...	4	4
[Middle Chalk]	Chalk and a few flints ...	72	—
	Chalk	20	—
	Hard chalk	4	—
	Very hard chalk	4	—
	Hard chalk	10	—
	Hard yellow chalk[1] ...	6	120
[Lower Chalk]	Chalk Marl [Belemnite Marl]	3	123
	Free-cutting chalk ...	31½	—
	Hard chalk	40½	—
	Sticky chalk	10	205

[1] Jukes-Browne suggested that this is Melbourne Rock.

The above refers to Boring No. 1. Three others have been made since, to the depth of 213, 218 and about 230 ft. They are within a few feet of one another.

The following particulars added from C. B. Purdom's book "The Garden City," 1913, p. 246.

Water in bore-holes 90–100 ft. below ground, according to the season.

18-in. bore to 220 ft. Tested up to 6,000 gallons an hour, reducing the water-level very little.

Second boring made in 1907. Third early in 1912, of 24 in. diameter, 210 ft. deep. All three borings within 60 ft. of each other.

Letchworth, cont.

While 50,000 gallons an hour were being lifted the level of the water was lowered by about 40 ft. On ceasing pumping water rose immediately 39 ft., and in six minutes to normal level.

Yearly consumption in 1905, 10,000,000 gallons.

The Local Government Board Return of 1915, p. 278, says:—"Supplies parishes of Letchworth and Willian . . . and furnishes a supply in bulk to Baldock . . . The average daily quantity of water obtained is 200,000 gallons." and much more could be got. *See* ADDENDA.

For analysis of this water, *see* p. 322.

Lilley.

Ordnance Map 221, new ser. (Herts. 11). Geologic Map 46, SE.

The Vicarage.

Made and communicated by R. B. PATEN.

Shaft 90 ft., the rest bored.
Chalk and flints, 226 ft.

London Colney, (? parish).

All Saints' Convent.

Made and communicated by Messrs. ISLER and Co.
45 ft. of 7¼-in. tubes, from 9½ ft. down.
Water level 17 ft. down.
Tested to 3,120 gallons an hour, 3rd March, 1900.

		Thickness. Ft.	Depth. Ft.
Well (the rest bored)		—	6
[Drift]	Sand	2	—
	London clay	24	—
	Running sand	4	—
	Rough gravel...	5½	41½
[Upper] Chalk		160	201½

Long Marston.

Ordnance Map 238, new ser. (Herts. 25, NW.) Geologic Map 46, SW.

1. Boarscroft Farm. North-west of the village.

About 270 ft. above Ordnance Datum.

Communicated by W. MAYNE and SONS of Stewkley.

Sunk 80 ft. and bored about 100, through clay [Gault] to rock, from which a little water rose into the well.

2. Gubblecote, near the stream at the end of the lane a mile east-south-east of the old church, and just outside the boundary of the Upper Greensand, 1885. Trial-boring for water to supply neighbouring villages.

Communicated by A. J. JUKES-BROWNE.
301 ft. above Ordnance Datum.
Water rose at first (April) to within 60 ft. of the surface, and in June it had risen to within 2 ft.

		Thickness. Ft.	Depth. Ft.
Upper Gault.	Soft blue sandy micaceous marl, yielding a little water	13	—
	Hard bluish sandy micaceous marl, almost a stone, and like Upper Greensand ...	30	—
	Grey sandy marly clay ...	26½	—
	Layer of phosphate-nodules with green sand at the base	½	70

Long Marston, cont.

		Thickness. Ft.	Depth. Ft.
	Dark blue clay with ferruginous stains	50	—
	Ditto, with lighter-coloured layers of iron-pyrites at 130 and 142	31	—
	Light-grey sandy clay ...	9	—
	Dark blue clay	11	—
	Light-grey sandy clay, with fragments of shells in the middle part	15	—
Lower Gault.	Light-grey calcareous clay, with a very hard rocky layer	1½	—
	Layer of phosphate-nodules	½	188
	Dark brown clay, with sand and shells, the lower part more sandy and with iron-pyrites	22	—
	Blue sandy clay, with phosphate-nodules at the base	3	—
	Hard light-coloured clay ...	2	215
	Hard sandy rock	6	—
Lower Greensand.	Ditto, with quartz pebbles	2	—
	Coarse white sand (chisel dropped)	2½	225½

Markyate Street, *see* Flamstead.

Mimms, North.

Ordnance Map 239, new ser. (Herts. 40, N.) Geologic Map 7.

1. Hawkshead House (at the north-western corner) 1¼ miles SE. of the church. Made and communicated by Messrs. Le Grand and Sutcliff. Supply 600 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Brickwork and concrete		—	1
Made ground		1	2
[Reading Beds]	Yellow clay	9	—
	Ballast [gravel] and water ...	6	—
	Blue clay	4	—
	Blue clay and pebbles	13	—
	Brown clay	1	—
	Iron-bound gravel	4	—
	Loamy clay and pebbles ...	2	—
	Loamy sand and pebbles ...	1	—
	Very hard coarse ballast ...	11	53
[Upper] Chalk and flints		127	180

Neither Drift or London Clay have been mapped here; but the section reads as if a little of both might be present.

2. For the Barnet District Water Co. Near the eastern side of the stream-course and south of Wise's Lane.

230 ft. above Ordnance Datum.

Made and communicated by Messrs. Docwra. Trial only, works not made. Shaft 31 ft., the rest bored.

	Thickness. Ft.	Depth. Ft.
Soil	½	—
Ballast [gravel]	16½	—
Clay and small shells	13½	—
Flints	½	31
[Upper] Chalk and flints. A layer of flints at 135 ft., others marked at 188–191, 210–210¾, and 218–218¾	225	256

For an analysis of the water, *see* p. 323.

Mimms, cont.

3. North Mimms Park.
Made and communicated by Messrs. S. F. Baker and Sons.
296 ft. above Ordnance Datum.
Water-level 81 ft. down.

		Thickness. Ft.	Depth. Ft.
Made ground		1	1
[London Clay] ...	Strong clay	18	—
	Pebbles and clay	1½	20¼
[Reading Beds, 28½ ft.]	Loamy sand and pebbles ...	2	—
	Soft light-coloured sand ...	8½	—
	Pebbles and sand	6½	—
	Loamy sand	1½	—
	Veins of clay and loam ...	4½	—
	Veins of clay and red sand ...	2½	—
	Clay flints and pebbles ...	2	49
[Upper] Chalk		111	160

Munden, Little.

Ordnance Map 221, new ser. (Herts. 21, N.E.) Geologic Map 47.
For Mr. J. Jollings.
Sunk and communicated by Messrs. Docwra.
Shaft 116 ft., the rest bored.
Water about 112 ft. down.

Surface-earth ...	1½	146 ft.
Chalk...	144½	

Public Well, Green End (? same as above). *R. Comm. Metrop. Water Supply Appendices*, 1893, p. 634.
Level of curb 370·23 ft. above Ordnance Datum.
Water-level, February, 244·65 ft, April, 244·06.
Other wells here are mentioned in the above report.

Northaw.

Ordnance Map 239 new ser. (Herts. 41, W.). Geologic Map 7.
For the Barnet District Water Co., 1904 ? 2 borings.
Made and communicated by Messrs. Docwra.

		Thickness. Ft.	Depth. Ft.
[? Drift] ...	Loamy clay	2	—
	Clay and pebbles	1	—
	Ironbound ballast	3	—
	Clean ballast	1¼	7¼
[London Clay and Reading Beds]	Yellow clay	2	—
	Sandy clay	8¾	—
	Hard white sand	6½	—
	Red sandy clay	4	—
	Yellow sandy clay	16½	—
	Blue sandy clay...	4	—
	Clay and pebbles	10	—
	Green sand	1½	—
	Flints	1	61½
[Upper] Chalk		3½	65
Another boring, 30 or 40 ft. off. 1905 ?			
Soil		¾	—
[? Drift] ...	Clay and stones	3¼	—
	Ballast	4	8
[London Clay and Reading Beds]	Yellow Loamy clay	9	—
	Sandstone	2½	—
	Yellow sand	9½	—
	Grey sand, a little water ...	8	—
	Brown sand and clay	14	—
	Black pebbles	9	—
	Flints	1	61
[Upper] Chalk		239	300

Northchurch.

Ordnance Map 238, new ser. (Herts. 25, SE.). Geologic Map 46, SW.

For the Grand Junction Canal Co. Cow Roast, close to the lock. 1849.
About 395 ft. above Ordnance Datum.
Communicated by S. C. Homersham.
Well 75 ft., the rest bored.
Water-level about 9 ft. down.

[River] Gravel	about	8	105 ft.
Soft chalk	„	65	
Hard chalk	„	32	

Norton.

Ordnance Map 221, new ser. (Herts. 7, NE.). Geologic Map 46, SE.
Western end of the village.

Information from J. Conder, well-sinker.

Sunk 71 ft., bored 30. The greater part through bluish clay with chalk-stones and boulders [Boulder Clay], with a thin seam of sand yielding a little water near the bottom (of the well). Below the sand is more of the like clay; but the boring is chiefly through clunch (chalk).

Nunsbury, *see* Cheshunt.

Offley, Great.

Ordnance Map 221, new ser. (Herts. 11, E.) Geologic Maps 46, NE., SE.

1, Offleyholes. ESE. of the village. 1896.
Made and communicated by Messrs. Merryweather.
Boring of 6 in. diameter.
Water-level 106 ft. down.

Chalk		24	124 ft.
Chalk Marl		26	
Chalk		74	

2. Wellbury House.
Made and communicated by Messrs. C. Isler and Co.
Water-level nearly 162 ft. down; but no supply of water.

		Thickness. Ft.	In.	Depth. Ft.	In.
Shaft (the rest bored)		—		133	6
	Chalk	41	2	174	8
[Melbourn Rock]	Rock	3	0	177	8
	Chalky marl	7	8	—	
	Hard chalk	5	0	—	
	Chalky marl	47	3	—	
	Hard stone	3	10	—	
[Grey Chalk, 91 ft.]	Hard marl	15	2	—	
	Gault	5	0	—	
	Very hard marl	2	9	—	
	Marl	2	10	—	
	Marl	2	2	269	4
[Totternhoe Stone, 9 ft.]	Hard stone	4	4	—	
	Marl	2	6	—	
	Hard stone	2	0	278	2
[Chalk Marl] ...	Marl	16	2	294	4

The divisions of the Chalk have been made by A. J. Jukes-Browne, who also notes that "Mr. R. Street, of Hitchin, says that the original well was sunk in 1822, and that the water-supply, though generally enough in winter and in spring, always partly failed in summer; hence the above boring was made in 1884, but without result. It was stopped by my advice. I recommended that the shaft should be deepened and headings driven. It was found necessary, however, to sink an entirely new well."

The old well (made in 1822) failed in the summer and autumn, 100 or 150 gallons drawn from it at one time would empty it, and it would be a day or two days before as much could be got again.

Oxhey, *see* Watford.

Patmore Heath, *see* Albury.

Perry's Green, *see* Much Hadham.

Pirton.

Ordnance Map 221, new ser. (Herts. 6, SE.). Geologic Map 46, NE.

1. North-west of the Church.

Made by C. P. Martin, of Harpenden. Communicated by Dr. W. Pollard.
A 4½ in. boring, through 115 ft. of Chalk Marl.
Sufficient supply for two cottages.
Judging from specimens, the Upper Greensand was not reached (A. Strahan).

2. Walnut-tree Inn, south of the Church.

Made by C. P. Martin. Communicated by Dr. W. Pollard.
Signs of Greensand at 70 ft.

[Lower Chalk].	Chalk Marl	20	120 ft.
	Blue clay-like chalk	50	
[? Chalk Marl]	Gault	50	

It must be more than 70 ft. to Gault here.

Ponsbourne Park, *see* Hatfield.

Puckeridge, *see* Standon.

Puttenham.

Ordnance Map 238, new ser. (Herts. 25, NW.). Geologic Map 46, SW.

In the field formerly worked for coprolites, about three furlongs south of the church, 1872 ?

About 290 ft. above Ordnance Datum.

From information got from the well-sinker by A. M. Brown, of Tring.
The thicknesses from A. C. G. Cameron's Notes.
Sunk 115 ft. and bored 110 ft.

Gault clay, with a rock at the bottom ...	? 150 ft.
Sand, without water	? 75 ft.
Dark (Kimmeridge) clay, with waterstones	—

This boring passed through either Lower Greensand or Portland Sand into the Kimmeridge Clay, and no water was found, that necessary for the coprolite-works being obtained from the canal near by. The thickness of the Gault here would be about 150 ft.

Radlett, *see* Aldenham.

Radwell.

Ordnance Map 221, new ser. (Herts. 7, NE.). Geologic Map 46, NE.

The Mill.

Information obtained from J. Conder, well-sinker, of Baldock.
Dug 22 ft., the rest bored.

		Thickness.	Depth.
		Ft.	Ft.
Moory soil		13	13
Chalk Marl	"Hurrock" or hard clunch	50	63
	Coprolites and greensand	1	64
Gault, with a layer of coprolites at the bottom		180	244

The boring was stopped without reaching the Lower Greensand.

Redbourn.

Ordnance Maps 238, 239, new ser. (Herts. 27, SW.). Geologic Map 46, SE.

One of 5 borings just below the village, for the supply of water to the mills on the river Ver (sunk by R. Paten), 1851, 1852.

Communicated by S. C. Homersham.

The five borings overflowed, yielding 750,000 gallons a day.

	Thickness. Ft.	Depth. Ft.
Soil and clay	3	3
Gravel	3	6
Chalk, mostly soft, but some hard, with four thick layers of flints	63	69
Chalk, with six beds of "rock" or "rocky chalk"	186	255

U. A. Smith says that the yield has "been gradually decreasing for a number of years; some of the boreholes have ceased to overflow, and the quantity coming from the remainder is now very small compared with what it was." *R. Comm. Metrop. Water Supply, Appendices*, 1893, p. 404. R. E. Middleton adds that one boring "is not to be found, and is supposed to have been covered by the railway. Two . . . were running pretty strongly, the other two weakly," but the outlets are below the level of the river. *Ibid.*, p. 590.

Reed.

Ordnance Map 221, new ser. (Herts. 8, NE., 9, NW.). Geologic Map 47.

Draft Report of Special Committee of Ashwell Rural District Council, November, 1913.

At Queensbury there is a "well into the Lower Chalk 450 ft. deep."

Rickmansworth.

Ordnance Map 255, new ser. (Herts. 43, E.). Geologic Map 7.

1. Batchworth Paper Mill (Messrs. Dickinson's). 1848.

Communicated by S. C. Homersham, C.E.

145 ft. above Trinity High-water mark.
Shaft about 13 ft., the rest bored.
Water-level about 7 ft. down. Supply 502,000 gallons a day.

[River] Gravel ... ... about	20	332 ft.
Soft chalk ... ... „	50	
Hard chalk, with fissures yielding much water	157	
Very hard chalk ... ... „	105	

2. Croxley Green, north-east of the town. The School. 1874.

Communicated by W. F. Vernon.

Mould	1	75 ft.
Clay	7	
Chalk (water rose 3 ft.)	67	

3. Croxley Green Laundry.

Information from Messrs. Cheeld and Co., of Chesham. 1911.

Red clayey gravel ...	36 ft. 4 in.	260 ft.
Chalk	223 ft. 8 in.	

4. Springwell Mineral Water Co., Mill End, close to where the Colne runs into the canal (S. of village). This place may be in Middlesex.

Made and communicated by Messrs. Isler and Co. (? 1919.)

20 ft. of 8½ in. tubes from a foot down. 101 ft. of 6 in. tubes from 2½ ft. down.
Water-level 1½ ft. down. Supply 1,800 gallons an hour.

Made ground	1	200 ft.
[River Gravel] Ballast	15	
[Upper Chalk] Chalk and flints	84	
[Upper Chalk] Hard chalk	100	

Rickmansworth, cont.

5. Loudwater Paper Mill (about a mile N. of the town). 1860.

Bored throughout, and communicated by R. B. PATEN.

Gravel and clay	15	220 ft.
Chalk with flints, and rock	205	

6. Shepherd's Farm, Mill End. 1877.

Sunk and communicated by C. BROWN (Harefield).

Shaft. 5 ft. of water.

Red gravel	10	33 ft.
Shingly gravel	5	
Chalk and flints	18	

7. Vicarage, Mill End. 1876.

Sunk and communicated by C. BROWN (Harefield).

Shaft. 5 ft. of water.

Gravel	15	34 ft.
Chalk and flints	19	

There are two other wells close by, one giving exactly the same section.

8. Water Company's Works.

Between the road and the river by Drayton Ford WSW. of Mill End, below the town. 1886?

J. W. GROVER. *Proc. Inst. Civ. Eng.*, vol. xc. pp. 18-20. And information from J. LUCAS.

149 ft. above Ordnance Datum and 10 above the river.

Shaft 26 ft., the rest bored. 20 in. diameter to the depth of 40 ft. (with 18-in. cast-iron pipes, carried up into the well). Then an 18-in. unlined boring to 100 ft., and then a 12-in. one to 300 ft.

Water rose to 3 ft. 2 in. above the adjoining river, the mouth of the well being 10 ft. above the river.

[River] Gravel, at least 20 ft.

Hard [Upper] Chalk with flints. Bed of nearly continuous flint at 51-96, 186-210, 247-257, and 288-300 ft. A substance like fullers' earth at 169-171½. Depth 300 ft.

The first trial-pumping was made when the boring was 201 ft. deep, at the rate of 14,000 to 15,000 gallons an hour. The water fell 5½ ft. in 12 months; but a further 5½ ft. fall took nearly two hours' pumping, after which the water gained on the pumps for an hour. After 4¼ hours pumping was stopped, and the water rose 6 ft. 1 in. in ten minutes and got back to within 3 in. of its original level in 38 minutes.

The second test was made when the boring had reached the depth of 300 ft., at first at the same rate of pumping, but increasing to 21,592 gallons an hour. The spring became weaker during the first hour, from some obstruction in the fissures in the Chalk, as, after 50 minutes, the obstruction having been washed out, the water gradually gained 16 in. on the pumps. At the end of 2¼ hours the pumps were stopped, and the water rose to within 2 in. of its original level in 37 minutes.

In the third trial the water came in more freely at first; after 50 minutes its level was 5½ in. higher than in the first trial and 2¼ ft. higher than in the second. During the next 1½ hours it fell a little below what it was in the second trial, but continued steady. The level of from 9 ft. 5 in. to 9 ft. 8 in. (down) seemed to be the general permanent depression of the water when the pumping was at the rate of 15,000 gallons an hour. After three hours' pumping the rate of 21,592 gallons an hour was set up and caused a further depression of less than 3 ft. at the most, and in the next hour the water gained slightly on the pumps. On leaving off pumping the water rose to its original level.

The average daily quantity of water got is 34,000 gallons (? per hour).

Rickmansworth, cont.

9. Water Co. Borehole at Batchworth Mills. 1902.

Made and communicated by Messrs. Docwra.

150 ft. above Ordnance Datum.

Water-level 3½ ft. down. 48 hours' pumping-test (May, 1902) lowered the water to 7½ ft. down. Approximate yield ¾ million gallons in 24 hours.

		Thickness. Ft.	Depth. Ft.
[Alluvium]	Dark loam	2	—
	Loamy peat	3½	5½
[River Gravel]	Ballast	12½	18
[Upper Chalk]	Hard chalk and flints ...	75	—
	Soft chalk, with layer of flints	15	—
	Hard sand chalk	4½	—
	Soft chalk and flints ...	150½	—
	Hard chalk and sand ...	37	300

The average daily quantity of water got is 634,000 gallons.

10. West Hythe (SW. of the town). Pinesfield.

Bored and communicated by Messrs. Isler and Co.

31 ft. of 6 in. and 5 in. tubes from 3¼ ft. down.

Water-level 4½ ft. down.

Yield tested with a 4-in. hand-pump, 1,440 gallons an hour.

Ballast [River Gravel]	23⅔	91 ft.
[Upper] Chalk and flints	67⅓	

Trouble was experienced with rubbly chalk falling in at 74 to 91 ft. down.

11. Woodcock Hill, south of the town.

For Mr. C. Haws, just about the Brick and Tile Works.

Made and communicated by Messrs Cheeld and Co., of Chesham.

Lined to 160 ft. with tubes of 4-in. internal diameter.

No water found above 160 ft., at which depth it rose to 130 ft. down. Yield tested at 170 ft. down and found to be only about 200 gallons an hour. Again tested at 206 ft., with little better result; and at 228½ ft. it was only about 375 gallons an hour, with the suction at 200 ft.

		Thickness. Ft.	Depth. Ft.
[Drift, or Wash]	Clay and flint	8	—
	Ballast [gravel]	1	9
[Reading Beds]	Mottled clay	30	—
	Sand	3½	—
	Mottled clay	½	—
	Sandy clay	1½	—
	Clay and black kidney-stones [flint-pebbles]...	3½	—
	Sand	½	—
	Clay and flints	9½	58
[Upper] Chalk, soft		170½	228½

12. Trial-borings made for G. Webster, 1890.

From "Pure Spring Water Supply for London . . . Report," by C. Moxckton, and from letters.

A. Station Field, just north of foot-bridge over stream, about 175 yards SSE. of St. Mary's Church.

About 154 ft. above Ordnance Datum.

Shaft 30 ft. to solid chalk; 40-in. boring to 100 ft.; the rest 30-in.

Water rose to the surface. The field was under water in May, 1896, gravel having been dredged from it.

Pumping 2,000,000 gallons a day lowered the water-level 16 ft.

Rickmansworth, cont.

		Thickness. Ft.	Depth. Ft.
[River] Gravel [? Alluvium above]		18	18
[Upper Chalk] ...	Chalk (? loose)	12	30
	Very hard chalk and flint ...	56	86
	Very hard grey chalk: no flint	22	108
	Hard grey chalk, with 5 in. of blue clay at the top and 8 in. of soft clay at bottom	29⅔	137⅔
	Grey chalk	46⅓	184
	? Carried to 200 ft.		

B. Wharflane Field, just SE. of Gasworks, near the Chess, and about 360 yards north-eastward of St. Mary's Church.

Shaft through gravel to [? firm] chalk, then a boring of 2 ft. diameter.

Water rose to 2½ ft. from the surface. Was 1½ ft. below the level of the stream in December, 1892. About the same May, 1896 ?

Pumping over 25,000 gallons an hour lowered the water 15 ft.

		Thickness. Ft.	Depth. Ft.
[River] Gravel [? Alluvium above]		15	15
[Upper Chalk] ...	(? Loose chalk)	10	25
	Soft grey chalk and flints ...	29	54
	Hard grey chalk and flints ...	30	84
	Very hard chalk and hard brown stone	31	115
	Grey chalk with flints	45	160
	Hard chalk: no flints	12	172
	Soft grey chalk: no flints ...	12	184

The greyness of some of the samples of Chalk is probably owing to moisture.

13. W. Topley has left a note of three borings 12 ft. deep below the watercress-beds over 500 yards NNE. of St. Mary's Church. The holes were plugged, and opened when needful. On 13th February, 1892, there was a run of 350,700 gallons (a day); but double this could be got if all the plugs were opened.

Ridge.

Ordnance Map 239, new ser. Geologic Map 7.

Tyttenhanger Pumping Station of the Barnet District Water Co. By Parkgate Corner, Colney Heath (Herts., 35, SE.).

From the Local Government Board and from F. J. Bancroft, Engineer to the Co.

241 ft. above Ordnance Datum.

Average daily supply 972,000 gallons.

			Thickness. Ft.	Depth. Ft.
Sandy soil			2	2
[Glacial Drift.]	Glacial Gravel.	Fine ballast	8	—
		Yellow Sand	1½	—
		Dirty ballast	4½	—
		Red sand	3½	19½
	Boulder Clay.	Blue clay	8	—
		Blue clay and pebbles	2½	—
		Yellow clay	1	—
		Yellow clay and pebbles ...	4½	35½
	Drift ...	Hard fine, dark sand	6½	—
		Clean ballast	3	45
	Flints, to chalk		1	46

[Upper] Chalk, presumably to some depth.

Royston.

Ordnance Map 204, new ser. (Herts. 4, NE. 5, NW.). Geologic Map 47.

Some years ago the county-boundary ran along the main street of the town, from east to west, so that whilst the southern part was in Hertfordshire, the northern was in Cambridgeshire. The county-boundary having been altered, the town is now wholly in the former county.

1. Royston Water Co. Works established 1859.

Made and communicated by Messrs. Isler and Co.

Lined with 10 ft. of tubes of 13½ in. diameter from 11 ft. down. Water-level 154 ft. down.

Soil	...	...	6	
Chalk	...	Chalk	97	280 ft.
		Chalk and shells	48	
		Chalk	96	
		Grey chalk ...	33	

Another boring (No. 2) passed through the same strata. Lined with 10 ft. of tubes 13½ in. in diameter.

Water-level 146 ft. down.

The works at Queen's Road have two wells, those at London Road one well and two bores.

An older account (published 1878) of the works, near the railway-station, says that a good spring was found 23 ft. down, and that a hard rock, 8 or 10 ft. thick, was found in the Chalk 40 ft. down.

The Local Government Board Return of 1915, p. 210, gives the average daily quantity of water available as 100,000 gallons and the supply as 80,000. "Chemically the water is very pure."

2. White Lion Inn, at the southern end of the town.

Water-level 120 ft. down. Chalk 150 ft.

3. Brewery. 4. Heath Farm.

Sunk and communicated by R. B. Paten.

3. Well 60 ft. Boring 105. Total 165. All Chalk.

4. „ 250 „ „ 111. „ 361. „

Rye Common, *see* St. Margarets.

Sacombe.

Ordnance Map 221, new ser. (Herts. 21, SE.). Geologic Map 47.

1. Sacombe Park. 1907 ? About 150 yards south-east of the house, in an old gravel-pit ?

About 365 ft. above Ordnance Datum ?

Made and communicated by Messrs. A. Williams and Co. with some notes from Dr. R. L. Sherlock.

Water rose to within 180 ft. of the surface, 1908. On April 24th, 1917, 173 ft. On September 12th, 1917, 181½ ft. 1,500 gallons an hour pumped, but the pump works occasionally only, and does not affect the water-level.

		Thickness. Ft.	Depth. Ft.
Dug well (the rest bored)		—	7
[? Reading Beds]	Loam sand	18	—
	Mottled sands	25	50
[Upper Chalk] ...	Chalk and flints	254	—
	Flints	2½	—
	Chalk and flints	33½	340

Various small wells (about 20 ft. deep) round about get the surface-water the level of which is about 4 ft. down.

Sacombe, cont.

2. Village Well. Sacombe Green.

R. Comm. Metrop. Water Supply. Appendices, 1893, p. 636.
Level of curb 352·23 ft. above Ordnance Datum.
Water-level 153 ft. down. Depth of well 169 ft.
Other Sacombe wells noted, p. 635.

St. Albans.

Ordnance Map 239, new ser. (Herts. 34, E.). Geologic Maps, 7, 46, SE.

1. Childwickbury. About 2 miles northward of the Cathedral.
Boring made and communicated by Messrs. ISLER and Co.
10 and 8½ in. tubes to 142 ft. from surface.
Water-level 134 ft. down.

On completion of the bore-hole the bore-pipes were disconnected and 15 ft. of suction lowered into the bore-hole. It took an hour and 20 minutes' pumping to get the water out of the dug well. After this was done about 10 minutes' pumping lowered the water right down to the bore-hole. The day after the withdrawal of the pump the water rose only to 144 ft.

Dug well (? old)	146	296 ft.
[Upper] Chalk	150	

2. Gorhambury. West of the town.
Made and communicated by R. B. PATEN.
Shaft 120 ft., the rest bored.

Clay, gravel and stones ...	15	320 ft.
Chalk and flints	305	

3. Hawkswick, north of the town and west of the Harpenden Road.
Made and communicated by R. B. PATEN.
Shaft 148 ft., the rest bored.

[Brick-earth and Clay-with-flints ?]	Clay and gravel ...	35	315 ft.
	Rock [flints ?] ...	6	
Chalk and flints		274	

4. Herts. Asylum. Just south-eastward of Hill End Station.
From Dr. BOYCOTT, Medical Superintendent.
289 ft. above Ordnance Datum.
Shaft, of 6 ft. diameter, 72 ft., the rest a 12-in boring.
Water first found 49 ft. down.

		Thickness. Ft.	Depth. Ft.
[Drift]	Yellow clay	7	—
	Soft marl	7	—
	Gravel	1½	—
	Loam and sand	11	—
	Gravel and sand	23	49½
[Upper Chalk] ...	Chalk with flints	12	—
	Hard chalk	7	—
	Chalk with flints	3¾	—
	Soft chalk	123½	195¼

According to the Local Government Board Return of 1915, p. 278, a supply is given to part of the parish of St. Peter Rural. "The average daily quantity of water obtained is 35,000 gallons." The quality is satisfactory. For analysis, *see* p. 325. The water is softened.

5. Napsbury. Middlesex County Asylum, about a mile west of London Colney.
243 ft. above Ordnance Datum.
From Dr. MUSTIN, Medical Superintendent, and Messrs. ROWLAND and PLUMBE.
Shaft, of 7 ft. diameter, 50 ft., the rest bored.
Rest-level of water 30 ft. down. When pumping, varies to 40 ft. down.
Average daily yield 100,000 gallons; could be increased to 200,000.

St. Albans, cont.

		Thickness. Ft.	In.	Depth. Ft.	In.
Drift	Clay	9	6	—	
	Loamy sand and pebbles	3	4	—	
	Blue clay and flints	—	6	—	
	Clay, sand and loose pebbles	5	6	—	
	Boulders	5	6	24	4
[Upper] Chalk		?266	3	290	7

Supplies also part of the parish of St. Peter Rural. The quality of the water is satisfactory. Local Government Board Return of 1915, p. 279.

6. New House Farm, a little south of the above.
Information from the occupier, to A. C. G. Cameron.

Sand and gravel		10	
Chalk	Chalk with flints	120	135 ft.
	Stone, from which the water is said to come [Chalk Rock ?]	5	

7. Shafford. (? Shafford Farm, by the Ver, north-westward of the city.)
Local Government Board Return of 1915, p. 278.

J. B. Joel. "Supplies Harpenden U.D. (part); parts of parishes of Redbourn, St. Michael Rural, and Wheathampstead" from a "Well in Chalk at Shafford. The average daily quantity of water obtained is 30,000 gallons," and more could be got. Quality satisfactory.

8. Ver House. 1897.
Made and communicated by Messrs. Duke and Ockenden.
Water-level 6 ft. down.

[Drift]	Sand and gravel	22	40 ft.
[Upper] Chalk	and flints	18	

9. Water Company's Works. Old Pumping Station, at the northern end of the town, close to Bernard Heath. 1865?
Communicated by A. F. Phillips.
About 410 ft. above Ordnance Datum.
The smaller and deeper well 1865. The larger 1877.
Shafts 200 and 180 ft., connected by a heading. Other headings also.
Boring, in the deeper shaft, to 66 ft. 30,000 gallons an hour have been pumped.

Gravel	30	266 ft.
Chalk, some very hard, about 100 ft. down	236	

A communication from R. B. Paten notes extensions of the newer well in 1882, the shaft being deepened 5 ft., headings driven, and boings of 140 ft. made, and gives the following section:—

Clay and gravel	60	325 ft.
Chalk and flints	265	

10. Water Company's Newer Pumping Station, at the foot of Holywell Hill, about 400 yards south of the Cathedral and about 250 ft. above Ordnance Datum.
The following particulars are from the *Herts Mercury*, reprinted in *Trans. Herts. Nat. Hist. Soc.*, 1887, vol. iv. p. 117.
All but top 4 ft. bored.
Boring lined for 50 ft. with wrought-iron tubes (? 8 in. and 18 in. borings). Water with a temperature of 50° F. Quantity 16,000 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Mould		3½	3½
[River Gravel]	Gravel, sand, etc.	3½	—
	Flints	3	—
	Red gravel and sand	14	24
[Upper Chalk]	Chalk and flints	37	—
	Hard flint	1½	—
	Chalk	3½	—
	Chalk rock	1	—
	Chalk	83	150

St. Albans, cont.

The Local Government Board Return of 1915, p. 211, gives contradictory figures for the yield of the waterworks wells. "The average daily quantity of water derived from" the newer works "is 700,000 gallons," and more could be got, "and 384,000 gallons from the older well, which is seldom used." But as to the quantity supplied, "the daily average is 636,000 gallons."

The Company supplies also parts of the parishes of St. Michael Rural, St. Peter Rural, St. Stephen, and Sandridge Rural. "The water is highly satisfactory." For analyses, *see* pp. 325, 326.

11. St. Peter's Rural? Windmill-pump, 300 yards NW. of Oaklands. From Dr. R. L. Sherlock.

Average water-level 65 ft. down.

Boulder Clay	... ...	10 to 20	90 ft.
Chalk	... ...	70 or more	

St. Margarets, or Stanstead St. Margarets.

Ordnance Map 239 new ser. (Herts. 30, SW., 37, NW.). Geologic Map 47.

Rye Common Pumping Station of the Metropolitan Water Board. About 440 yards southward of the church, on the parish-boundary with Great Amwell, between the road and the New River, 1885.

Ground 101 ft. above Ordnance Datum. Engine-house floor 110·5 ft. above Ordnance Datum.

Made and communicated by Messrs. Docwra.

Shaft and cylinders 197 ft. (? 204½). Headings of 69 (North) and 286 ft. (South) with bottom 159¾ ft. below engine-house floor.

In 1896 the water-level was given as 94·15 ft. above Ordnance Datum.

Average yield about 4,000,000 gallons in 24 hours (J. M. Wood, 1920).

		Thickness. Ft.	Depth. Ft.
[River Drift]	Loam and stones	3½	—
	Sandy loam	1	—
	Loamy Clay	1½	—
	Gravel	7¾	13¾
[Upper Chalk] 187½ ft.	Chalk and flints	1¼	—
	Soft chalk	?61	—
	Chalk and flints	?61	—
	Chalk	64½	201½

J. Francis has given the depth to the Chalk as 15 ft., and the yield as 3,750,000 gallons a day.

Sandon.

Ordnance Map 221, new ser. (Herts 8, NE.). Geologic Maps 47 and 46, NE.

Vicarage.

Made and communicated by G. Ingold.

[Boulder] Clay, with sand at the bottom, 30½ ft.

Sawbridgeworth.

Ordnance Map 240, new ser. (Herts. 31, W.). Geologic Map 47.

1. Chandler's Green. ? WNW. of village.

Sunk and communicated by G. Ingold.

Shaft 55½ ft, the rest bored. Little water.

White and blue Boulder Clay	33½	
Sandy loam	1½	
Gravel, top 10 ft. red, the rest yellow and sandy	18	60½ ft.
Black sandy clay	2½	
Mottled loam	5	

Sawbridgeworth, cont.

2. Hertfordshire and Essex Waterworks (in field 393 of Tithe Map). Communicated by E. Easton.

Shaft about 75 ft., the rest bored.

		Ft.	In.
[Drift, 31½ ft.]	Dark brown clay with flints	11	6
	Gravel	1	6
	Dark brown clay with flints	4	0
	Gravel	14	6
[London Clay, 43 ft.]	Blue loamy clay	25	0
	Basement Bed. { Dark sand with water	3	3
	Basement Bed. { Sand and rock ...	1	3
	Dark sand with water. [This may belong to the basement-bed of the London Clay]	13	0
[Reading Beds, ? 62 ft.]	Mottled clay	13	0
	Dark sand	9	0
	Yellow loamy sand with small pebbles ...	6	0
	Green sand with a little water	34	0
	To Chalk	136	0

Some specimens from a trial-bore differ somewhat, as follows:—

[Basement Bed of London Clay].
- At 47 ft., loam with green grains, 2 ft.
- „ 51¾ ft., brown loam.
- „ 53 and 62½ ft., brown clayey sand.
- „ 68, 74, and 79 ft., red mottled, light-coloured and brown mottled clays.
- „ 91 ft., clayey sand.
- „ 94, 104, 124 ft., fine buff sand.
- „ 96 ft., deep red (ferruginous) sand.
- „ 132 ft., chalk.

An account from G. Ingold, received later, differs in particulars, and may therefore be given. It is as follows:—

Iron cylinders 150 ft., the rest bored.

		Ft.	In.
	Mould	1	0
[Drift, 33½ ft.]	Dark brown clay	6	0
	Brown clay	7	4
	Sharp sand	2	0
	Brown clay...	0	8
	Blue clay	3	0
	Gravel, the second ½ ft. a conglomerate	7	0
	Loam	1	0
	Gravel	0	6
	Fine sharp sand	2	0
	Gravel	3	0
[London Clay, 41½ ft.]	Dark blue clay	22	6
	Dark sandy clay	5	0
	Hard sand rock	2	6
	Dark sandy clay	11	6
[Reading Beds, 64 ft.]	Light-green clay	1	6
	Light-brown clay	2	0
	Light-bluish clay	8	6
	Strong brown clay	3	0
	Black sand	6	0
	Greenish sandy loam	1	0
	Very hard red clay	0	6
	Green sand	1	0
	Yellow sandy loam with black pebbles...	5	6
	Greenish-grey sand and sandy loam ...	29	0
	Dark slate-coloured clay	5	0
	Green-coated flints	1	0
	To Chalk	139	0
Chalk with flints; at a depth of 250 ft., with black veins, shells, and nodules of iron-pyrites		111	0
		250	0

Sawbridgeworth, cont.

The Herts and Essex Waterworks Co. supplies the parish of Sawbridgeworth (part); but the rest of its many places of supply are in Essex. The water is excellent (Local Government Board Return of 1915, p. 197.)

According to the Water Works Directory, 1911, p. 171, the yearly quantity supplied was 105,000,000 gallons.

For analysis of the water, *see* pp. 326, 327.

3. North End. Mr. Poole's new house. (? 1883 or 1884.)

Sunk and communicated by G. Ingold.

Shaft, no water.

[Drift] ...	Brown sand and loam ...		20	50 ft.
	Boulder Clay	White clay and stones	17	
		Blue clay	13	

4. According to the same authority another well, a few yards from the Station Road, is 58½ ft. deep in blue clay and gravel.

5. Shingle Hall. 1890.

Made and communicated by G. Ingold.

Shaft 25 ft., the rest bored. Water rose nearly to the surface.

Glacial Drift...	Yellow Boulder Clay ...	25	30 ft.
	Loose sandy chalk ...	5	

6. Spelbrook, Lane north of the village. 1889.

Made and communicated by G. Ingold.

Water at 23 ft.

Made ground		1	
[Drift] ...	Brown clay	10	
	Gravel	1	
[? London Clay.]	Yellow loam	3	41 ft.
	Black sandy loam ...	8	
	Brown clay	11	
	Dark brown clay	7	

A well at Allen's Green, to the NW., is 25 ft. deep, in white and blue Boulder Clay (same authority).

7. Spelbrook (N. of the village). New Mission Schools. 1890.

Made and communicated by G. Ingold.

Well. Water 16 ft. down.

Brown clay	4	22 ft.
Yellow sandy loam	16	
Grey sandy loam	2	

8. Woolrych's. 1870.

Made and communicated by G. Ingold.

Strong spring. Water at 38 ft. down.

Clay	28	39¾ ft.
Gravel	11¾	

According to a return sent to the Local Government Board in 1911, the parts not supplied by the Herts and Essex Co. consisted of 33 houses in the town, supplied by wells, and 28 in the hamlet of Spelbrook, supplied from springs The water was good.

Shephall.

Ordnance Map 221. (Herts. 20, NE.). Geologic Map 46, SE.

Shephallbury. 1885.

Made and communicated by Messrs. Tilley.

		Thickness. Ft.	Depth. Ft.
Drift	Old well	—	80
	Sand	4	84
Chalk		36	120

Shenley.

Ordnance Map 239, new ser. (Herts. 40, W.). Geologic Map 7.

1. All Saints' Convent (Colney House of the Map), NNW. of the village.
Made and communicated by Messrs. Isler and Co.
45 ft. of 7¼-in. tubes from 9½ ft. down. Water-level 17 ft. down.

		Thickness. Ft.	Depth. Ft.
Well (the rest bored)		—	6
[Glacial Drift] ...	Sand	2	—
	London Clay [Boulder Clay] ...	24	—
	Running sand	4	—
	Rough gravel	5½	41½
[Upper] Chalk		160	201½

2. Pasters, westward of the village.

Made and communicated by Messrs. Le Grand and Sutcliff.
Water-level 192 ft. down.

Well (the rest bored) [London Clay and Reading Beds]	200	273½ ft.
[Upper] Chalk and flints	73½	

Standon.

Ordnance Maps 221 and 239, new ser. (Herts. 21, SE., 22.) Geologic Map 47.

1. Puckeridge, north-eastward of the village. Mr. G. Carey's.
Made and communicated by Messrs. Le Grand and Sutcliff.

		Thickness. Ft.	Depth. Ft.
Dug well (the rest bored)		—	19
[Glacial Drift] ...	Blue [Boulder] clay	5	24
	Dry gravel	8	32
Chalk		54	86

2. Ware Gun Station, Bartram's Farm, 1½ miles S. of the village. 1916. Deepened 1917.

A boring, communicated by H.M. Office of Works, 310 ft. above Ordnance Datum.

160 ft. of 4½-in. tubes and 56 ft. of 3½-in., the rest open and of 3¼-in. diameter.

Water-level at beginning of pumping 184½ ft. above Ordnance Datum; at cessation of pumping 125. After deepening the figures are given as 224 ft. and 110. The water returned to its original level in ten minutes.

Yield 350 to 400 gallons an hour; later given as 240 after the boring had been deepened.

		Thickness. Ft.	Depth. Ft.
[Boulder Clay] ...	Brown clay, full of large flints ..	16½	—
	Blue clay, with traces of chalk and flints	9½	—
	White marl	55	—
	Light-brown clay	3	—
	White marl	30	114
[Drift or Eocene ?]	Brown pebbles	2½	—
	Clay	3	—
	Flints	½	120
[Upper Chalk] ...	Bull-head chalk, rotten and yellow	33	—
	White chalk and flints	46	—
	Yellow slurry	11	—
	Chalk and flint	134	344

3. The following notes are from Dr. R. L. Sherlock.

At Colliers End, a hamlet SE. of the village, a well, 50 ft. deep, in clay and chalk, had 10 ft. of water. At Libden's Farm, just SSW. of Colliers End, a well, through 40 ft. of clay and chalk, had 10 to 12 ft. of water, and it does not fail. At Marshalls, High Cross, is a well about 120 ft. deep, with a boring of 110, at 281 ft. above Ordnance Datum. Water-level about 110 ft. down.

Stanstead Abbots.

Ordnance Map 239, new ser. (Herts. 30, SW.) Geologic Map, 47.
Little Briggins, north-eastward of the village. 1901.
Made and communicated by Messrs. Duke and Ockenden.
Water-level 103 ft. down (2 ft. of water in the dug well, from gravel ?)

		Thickness. Ft.	Depth. Ft.
Dug well, old, the rest bored		—	48
[Drift]	Gravel and sand (from 46 ft. down)	9	57
[Reading Beds]	Clay mixed with sand	12	69
[Upper] Chalk and flints		84	153

According to the map one would expect London Clay next beneath the Drift.

Stanstead St. Margarets, *see* St. Margarets.

Stevenage.

Ordnance Map 221, new ser. (Herts. 12, SE.). Geologic Map 46, SE.

1. For the Great Northern Railway Co. By the western side of the railway, S. of Langley Siding.

A 7¼-in. boring. Made by Messrs. Le Grand and Sutcliff. Details, to 113 ft., given by W. Hill, *Proc. Geol. Assoc.*, 1912, vol. xxiii, p. 218. (Moulded printed by mistake for Mottled.)

Chalk water-level 66⅓ ft. down.

Yield at trial-pumping, at a depth of 300 ft., 2,700 gallons an hour. At 400 ft. 3,100, slightly increased at 450. This being insufficient, the well was closed.

		Thickness. Ft.	Depth. Ft.
Top soil...		½	—
[Glacial Drift] ...	Stony brown clay	13½	—
	Stony blue clay with little water	18½	—
	Mottled loamy clay	5	—
	Brown gravel	45	—
	Blue clay	6½	—
	Mottled clay	4	—
	Flint stone and pebbles ...	3	—
	Sandy gravel	11	—
	Loamy gravel	2	—
	Loamy clay	4	113
[Upper and Middle Chalk]	Chalk	147	—
	Chalk and flints with occasional hard bands	30	—
	Hard chalk and flints	10	—
	Very hard chalk	30	—
	Soft chalk, water-bearing ...	8	—
	Sticky chalk	55	—
	Chalk, water bearing	7	400
	Deepened to	50	450

For an analysis of the water, *see* p. 328.

2. Orchard Court. By the railway, SSE. of the Station.

Information from J. B. Denton.

From 1874 to 1881 the depth of water in the well (70 ft. deep) varied from 1 ft. 7 in. on 1st January, 1875, to 21 ft. 3 in. on 1st July, 1881. The measurements only half-yearly. The variation goes generally with the rainfall. The water is from Drift, over Chalk.

In his "Sanitary Engineering" (London, 1877), p. 110, measurements on the first of each month, from January, 1874, to May, 1876, are given, with a variation from 1 ft. 1 in. in April, 1876, to 7 ft. 10 in. in May, 1876.

Stevenage, cont.

3. Titmore Green (? parish. NW. of the town). Mr. A. W. Young's.

Made and communicated by Messrs. A. Williams and Co.

Water-level 53 ft. down. Yield said to be unlimited.

[Drift] ...	Loamy clay ...	30	117 ft.
	Hard flints ...	8	
[Upper Chalk] ...	Chalk	37	
	Chalk and flint ...	42	

4. Waterworks. S. of Rook's Nest, ¼ mile NE. of St. Nicholas Church.

479 ft. above Ordnance Datum.

Information from Mr. Pickett.

Two wells, 35 ft. apart (from centre to centre), connected by a heading. The older well a shaft of 20 ft., the rest bored, to 254 ft. The newer well a shaft of 181 ft., of 6-ft. diameter, enlarged to 16 below.

Water-level 154 ft. down. Yield 6,000 gallons an hour. Well can be pumped dry in eight hours.

Water not so hard as that from wells in the town.

All in Chalk with flints, chiefly soft. At 107 ft. loamy pockets, with black flints, on one side, for 10 ft. At 138½ ft. some water from a fissure. At 150 ft. some hard chalk on one side. At 165 ft. chalk very hard, with a shining appearance.

Outside the building is a 6-in. boring to the depth of about 440 ft.

According to U. A. Smith (*R. Comm. Metrop. Water Supply*, Appendices, 1893, p. 409) between 1878 and February, 1891, the normal water-level had gone down 13 ft. According to R. E. Middleton (*ibid.*, p. 563) "it is now pumped dry every day."

A. J. Jukes-Browne, in his Memoir on the Cretaceous Rocks, vol. iii, p. 232, says: "In 1886 a well was sunk at a spot about a quarter of a mile east of Stevenage Church, and the following particulars . . . were obtained by Mr. W. Hill." This may refer to the second well at the Waterworks, and, if so, gives a somewhat different, and more likely, reading of the beds.

White [Upper] Chalk with flints	112	125 ft.
Chalk Rock (sample seen)	3	
White [Middle] Chalk	10	

"The average daily quantity of water obtained is 75,000 gallons," and more could be got. Quality good. Local Government Board Return of 1915, p. 134.

Information on wells 5–8 got by A. C. G. Cameron.

5. Public pump (? an old one, in the town). Emptied by pumping in three hours. Fills again in about the same time.

6. South End. They usually dug through 30 to 33 ft. of clayey gravel to get water.

7. House on the eastern side of the road by the southern end of Cuckoo Wood.

Glacial Drift ...	Boulder Clay	20	84 ft.
	Sand and gravel, with thin clay (in the middle ?)	64	

8. White Lion Inn. Clayey gravel, 70 ft.

9. On the western side of the road just north-west of the railway-station. Abandoned.

Got by B. E. L. Culpin, from local information. Figures approximate only.

[Glacial Drift]	Loam	1½	Over 77 ft.
	Rubbly clay	5	
	Rubbly gravel	5	
	Clay	10	
	Boulder clay	25	
	Blue clay	30	
	Concretions, 4 in.		
	Sand with water.		

Stocking Pelham.

Ordnance Map 222, new ser. (Herts. 14, NE.). Geologic Map 47.

Mr. Richardson's Cottages.

[Glacial Drift]	Boulder Clay	30	113 ft.
	Sand	15	
[Upper] Chalk	... ...	68	

Tewin.

Ordnance Map 239, new ser. (Herts. 28, NE., 29, NW.). Geologic Map 46, SE.

1. A. C. G. Cameron noted a well at Upper Green, which passed through 15 ft. of heavy (Tertiary) clay and 165 of Chalk. Also one at Hoo Hall, which, passing through clay and sand, reached Chalk and went to the depth of 200 ft.

The following two wells from the engineer in charge, to Dr. R. L. Sherlock. 1914.

2. Tewinwater, near the house.

Over 200 ft. above Ordnance Datum.

80 ft. deep, 30 ft. to water.

Gravel 30 to 40 ft., the rest Chalk.

3. Tewinwater Laundry. About 1,000 yards east of the house.

About 20 ft. to water, about 80 ft. deep: sand and gravel 30-40 ft., the rest Chalk.

Therfield.

Ordnance Map 221, new ser. (Herts 4, SE., 8, NE.). Geologic Map 47.

1. Rectory.

Communicated by the Rev. J. G. Hale. 1903.

509 ft. above Ordnance Datum. Sir G. Fordham gives the figure 512.

In 1897, after the very wet autumn of 1896, there was 62 ft. of water at the end of May. There was no water after 31st December, 1901.

Stiff clay (found in tank close by)	10	276 ft.
Chalk	266	

The following particulars from a paper by Sir G. Fordham in Trans. Herts. Nat. Hist. Soc. 1890. Vol. vi, pp. 31, etc.

Well originally 10 ft. less in depth (266 ft).

A monthly record of the water-level was kept by the Rev. J. G. Hale, from 1st January, 1883.

The chart (plate ii) shows the monthly water-levels in the wells at Therfield, Barley (*see* p. 179) and Odsey (just over the border, in Cambridgeshire) from 1st January, 1883, to 1st March, 1889, in the first case; from 1st April, 1878, to 1st October, 1887 (with some gaps) in the second; and from 1st December, 1879, to 1st October, 1889 (also with gaps) in the third.

Sir G. Fordham has been kind enough to take much trouble in looking up the record, and we are indebted to him for the following information.

The records were continued after Mr. Hale's death; but for a short time the present rector, the Rev. A. R. Humphreys, was unable to find those from 1889 to 1905. Of those from 1906 onward, the first two years are in Mr. Hale's handwriting. Since his death the gardener has kept the records.

In 1908 the method of measurement was changed, and, instead of the depth of water in the well, the depth to the surface of the water is given [this is a better and more convenient form, as it avoids all question as to the depth of the well] and this is only a reversion to the method of 1883-5, when both figures were given. Also from 1909 onwards the measurements were taken on the first day of a month, instead of on the last, as was the case from 1888 to 1908. The first seems also to have been the day before 1888.

The following is a condensed account of this long record, giving the highest and lowest monthly records.

1883. Depth to water 192 ft. in April, 234 in January.

1884. Depth to water 213 ft. 10 in. in April, 235 ft. 8 in. in December.

Therfield, cont.

1885. Depth to water 239¾ ft. in January. In August it was found that the measuring string had stretched largely. Depth of water in well 19¼ in December.
1886. Depth of water in the well 47¼ ft. in August, 20 ft. 10 in. in January.
1887. Depth of water 48 ft. on 1st May, 23 on 31st December.
1888. Depth of water 26 ft. in July, 18¼ in March.
1889. Depth of water 41 ft. 5 in., in July and August, 20 ft. 2 in. in January.
1890. Only two records, March 37½ ft., September 33.
1891. Only four records, January 21 ft. 8 in., March, August, and October 14½ ft.
1892. Depth of water in the well 52 ft. 4 in. in April, 31 ft. 4 in. in October. No records for February, August and November.
1893. Depth of water 64 ft. in April, 26½ in December. No records for January, October and November.
1894. Depth of water 30 ft. in April and May, 16 ft. 10 in. in November. No records for March, June, August, September and December.
1895. Depth of water 32¾ ft. in May, 20¾ in December. No records for January, July and September to November.
1896. In June the depth of water was 33 ft., in March 29¼. July the only other month recorded.
1897. Depth of Water 62¾ ft. in May, 28 in December. No records for January, April and August to November.
1898. Depth of water 17½ ft. in May, 3½ in December. No records for January to March.

On 29th November an assistant of B. Latham's examined the well, and made the depth 274½ ft., or 1½ less than Archdeacon Robinson recorded in 1859. This may be accounted for by what may have fallen in from the sides or otherwise since that time.

1899. Water in well 16 ft. 10 in. in June, 4 ft. in January. February omitted.
1900.[1] Water in well 30 ft. 1 in. in June, 5 ft. 2 in. in January.
1901.[1] Water in well 8 in. in December, 12 ft. 8 in. in June.

[1] In 1900 and 1901 the water-level is also given ; but the figures do not agree with those for water in the well. But it is said that after the Surveyor's visit in November, 1898 the depth of the well was taken as 274½ ft., instead of 276; but it is thought that the latter is right, and after 1901 that figure was reverted to.

1902. No water in the well, until June, 1903.
1903. Latter half, water in well 16½ ft. in December, 6 in July.
1904. Water in well 51 ft. 2 in. in March, 19 ft. in December.
1905. Water in well 16 ft. 10 in. in January, 5¼ ft. in December.
1906. Depth of water in the well 15 ft. 5 in. on 30th June, 4½ ft. on 30th November and 31st December.
1907. Depth of water 18½ ft. on 30th April, 7 ft. on 31st January.
1908. The water-level, below the sill of the well, 261½ ft. on 30th April, 239 ft. 10 in. on 29th February.
1909. Water-level 269 ft. 2 in. on 1st April, 262 ft. 2 in. on 1st January (which was 3 ft. 1 in. higher than on 31st December, 1908).
1910. Water-level 264 ft. 1 in., in January, 236 ft. 10 in. in July.
1911. Water-level 255 ft. 7 in. in December, 235 ft. 7 in. in May.
1912. Water-level 257 ft. 5 in. in February, 230 ft. 8 in. in June.
1913. Water-level 248 ft. 7 in. in December, 223 ft. 8 in. in June.
1914. Water-level 259¼ ft. in December, 247 in July.
1915. Water-level 260 ft. in January, 216 ft. 5 in. in June.
1916 (half). Water-level 226½ ft. in April, 194 ft. 8 in. in June.

On Plate I of Sir G. Fordham's paper a section is given showing the changes of water-level from Therfield northward to the foot of the chalk-escarpment at Litlington, where the nearest springs occur, about four miles off.

2. According to a Report of a Special Committee of the Ashwell Rural District Council "the Public well on the Green has afforded an almost unfailing supply and (which) on analysis has proved of good quality." Other supplies come from rain-water and from (ponds in) Boulder Clay, and there are several wells. (Information from the Local Government Board).

Thorley.

Ordnance Map 222, new ser. (Herts. 23, SW.). Geologic Map 47.

1. Rectory. 1888.

Made and communicated by G. Ingold.

Mould			2	21 ft.
[Boulder Clay.]	White clay		8	
	Blue clay		10	
	Rubble		1	

2. Rumball's Farm. Half a mile north by west from the Church. 1894.

Mode and communicated by G. Ingold.

Shaft 25 ft., the rest bored.

Soil			2	31 ft.
[Drift?]	White clay		7	
	Brown clay		7	
	Blue clay		14	
	Sand, with water		1	

3. Thorley Street. By road-side.

Shaft made and communicated by G. Ingold.

Water at 17½ ft.

Mould	1	21 ft.
Blue and brown clay in patches	9	
Yellow sand and clay	3	
Yellow sand	4	
White sand	4	

4. Twyford Bury. 1896.

Boring made and communicated by G. Ingold.

Water rose to 14 ft. from the surface.

	Thickness. Ft.	Depth. Ft.
Brickearth	12	—
Sand	2	—
Hard red brown clay	5	—
Sandy gravel	36	—
Live sand	25½	—
Brown clay	½	—
Yellow loamy sand	23	104
Grey clay	1	—
Yellow loam	15	—
Blue clay	1	—
Chalk	49	170 (given as 160).

5. Twyford House. A mile south of Bishop's Stortford. 1894.

Boring made and communicated by G. Ingold.

Water, from the Chalk, rose to a foot above the ground. Yield from 30 to 40 gallons a minute.

		Thickness. Ft.	Depth. Ft.
Made ground		6	6
[? Drift, London Clay and Reading Beds].	Green sandy loam	1	—
	Black gravelly clay	3	—
	Black peaty clay	2	—
	Grey sandy loam	33	—
	Yellow sandy loam	16	61
Chalk		59	120

6. Whitelands. 1888.

Bored and communicated by Messrs. Le Grand and Sutcliff.

About 285 ft. above Ordnance Datum.

Water-level 112 ft. down.

Thorley, cont.

		Thickness. Ft.	Depth. Ft.
Dug well [? Boulder Clay]		—	20
[Glacial Drift]	Boulder clay	42	—
	Loamy clay and water ...	4	—
	Boulder clay	3	—
	Ballast [gravel]	10	79
[London Clay? and Reading Beds]	Clay	2	—
	Sand	11	—
	Mottled clay and sand ...	8	—
	Blue loamy sand	10	—
	Mottled clay and sand ...	13½	—
	Pebbles and flints ...	2½	126
Chalk ...	Chalk and flints	5	—
	Discoloured chalk ...	16	—
	White chalk and flints ...	53	200

Thundridge.

Ordnance Map 239, new ser. (Herts. 30, NW.). Geologic Map 47.

Information as to a number of wells in this parish has been collected by Dr. R. L. Sherlock, from which the following notes come.

1. Cowards Farm. South of Thundridge Bury.

About 8 ft. of water.

Gravel	18–20	122 ft.
Chalk	102 or more.	

2 Swangles (east of Thundridge hill), about 100 yards south-east of.

Well 80 ft.; bricked 40 ft., on to Chalk. About 8 ft. of water, rising to 14 when at rest. Other wells round about.

3. Poles Estate. *See also* Ware, Rural.

(*a*) Lodge 800 yards north-east of house. About 255 ft. above Ordnance Datum. 6 ft. of water; but fails in a dry season.

Clay	30	119 ft.
Chalk	89	

(*b*) Downfield Farm. 350 yards north-west of the house. Fails in summer. Well about 120 ft. deep: half gravel and sand, half chalk.

(*c*) Moles Farm, 1,100 yards east of the house. Well about 100 ft. deep, bricked for 40; mostly clay. About 8 ft. of water: does not fail. Another well only 32 ft. in clay, to chalk, with about 7½ ft. of water.

Tring.

Ordnance Map 238, new ser. (Herts. 25). Geologic Map 46, SW.

1. Bulbourne, northward of the town. For the Canal Co. A boring at the lock. 1855.

A. J. Jukes-Browne. Cretaceous Rocks, vol. ii, p. 177. From examination of specimens.

		Thickness. Ft.	Depth. Ft.
Lower Chalk.	Soft chalk	20	20
	Hard grey sandy chalk (Totternhoe Stone) ...	9	29
	Soft chalk marl	5	34
	Soft bluish marls	25	59
	Soft grey marl, with harder lumps	10	69
	Grey micaceous silty marl	2	71
	Hard rocky chalk, with impression of *Ammonites varians* at 71½ ft. ...	? 4	75
	Soft grey and blue clayey marls	? 65	140

Tring, cont.

		Thickness. Ft.	Depth. Ft.
	Soft micaceous grey and greenish sandy marls ...	10	150
	Light-grey clays	80	230
Gault, 258 ft.	Clay with phosphatic nodules	1	231
	Clays	159	390
	Clay full of sand and pebbles	8	398
Lower Greensand.	Brown sands	62	460
	Greenish sand	5	465

Both the Chalk Marl (the beds between the Totternhoe Stone and the Gault) are thicker than usual, the former being 111 ft. It is given as 115 in a MS. of JUKES-BROWNE's, which differs in some details, and gives a fuller account of the Lower Greensand, making the Gault only 232 ft. thick, and carrying the boring 12 ft. deeper, as below. (The words in these brackets added from an old MS. ? of PRESTWICH).

		Thickness. Ft.	Depth. Ft.
	Grey sand and pebbles, mixed with clay ...	8	398
Lower Greensand.	Coarse brown sand-rock (clayey sand)	42	440
	Loose brown sand (clayey)	20	460
	Greenish sand (coarse to 463 ft.)	5	465
	Coarse grey sand	12	477

In vol. i of the Cretaceous Rocks, p. 279, the thickness of the Gault is given as 238 ft.

2. Grove Place, about ¾ mile NE. of the town.

Communicated by A. M. BROWN, of Tring.

Sharp sand and gravel, 18 ft.

3. Two borings for water for the Grand Junction Canal. 1827.

W. GRAVATT, *Trans. Inst. Civ. Eng.*, vol. i, p. 151.

25 ft. below summit-level of hill near Marshcroft Bridge [a name not on the map].

	Thickness. Ft.	Depth. Ft.
Chalk	20	20
Hard blue clay	30	50
Blue stone	4	54
Hard blue clay	47	101

At the depth of 54 ft. water rose to the top and ran over at the rate of 1,300 cubic feet in 24 hours. No more was got by boring lower.

In the same hill, and 20 ft. from the summit-level (of the canal).

	Thickness. Ft.	Depth. Ft.
Chalk	30	30
Hard blue clay	34	64
Blue stone, from which water rose up ...	4	68
Blue clay } with layers of hardened clay at	82	150
Black grit } about every 4 ft.	10	160
Very hard blue clay	108	268

It is interesting to know that these borings were three months in hand and cost only £145.

Tring Railway Station is in the parish of Aldbury, *see* p. 173.

Tyttenhanger, *see* **Ridge.**

Walkern.

Ordnance Map 221 new ser. (Herts. 13 W.). Geologic Map 46, SE.

1. Victoria Brewery.

From notes by Mr. Holland, manager, 1876, and some later information.

Level of curb 280 42 ft. above Ordnance Datum.

Old shaft 100 ft., the rest bored.

Water from the bore-holes stands 12 ft. down [? in bore-hole].

Yield 12 barrels an hour (1887)

According to R. E. Middleton "there is a suspicion on the part of the owners that it is affected by surface water." *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 564.

Soil		
[Boulder Clay.] Blue clay and chalk-stones, with gravelly seams	200	300 ft.
Soft chalk, with a very hard bed at the top	100	

The above section seems to point to the occurrence of a deep mass of Glacial Drift in the Chalk valley, perhaps a channel of a like kind to that in a neighbouring part of Essex (Cam Valley), described in *Quart. Journ. Geol. Soc.*, 1890, vol. xlvi, pp. 333–340.

2. Farm close to Wright's Brewery (? the above). 1874.

A. C. G. Cameron notes that Red loam and flint was found to the depth of 40 ft.; but that at one side Chalk was found 15 ft. down. This looks like a pipe of Drift.

R. E. Middleton says, presumably of this well, "the well at Wright's Farm, which is the largest well in Walkern with the exception of that at the Brewery, and which is said to penetrate [into] the chalk, contained only 4 ft. of water 17 years ago. If this be true the chalk water level must have been 37 ft. below the river, and there could be no possible connection between it and the springs above Walkern church." *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 564.

The following (3–12) are from A. C. G. Cameron's notes. His information was got chiefly from Mr. Aldridge, well-sinker:—

3. Boxhall Farm, a mile west of the village [this may be either Boxbury Farm, 1½ mile westward of the church, or Boxfield Farm, on the other side of Box Wood, about 1¾ miles WSW. of the church, presumably the latter].

Clay [? Clay with flints]	30	190 ft.
Chalk	160	

4. Clay End, about 1¾ miles SE. of the church.

Blue loam [weathered Boulder Clay] ...	40	170 ft.
Chalk	130	

5. Clay End Cottage.

[Boulder Clay]. Blue clay and chalk-stones	80	100 ft.
Chalk	20	

6. Holmes Farm, 1½ miles SE. of the Church.

Water-level varies from 7 to 20 ft. in the well.

Clay and stone [Boulder Clay]	30	150 ft.
Chalk...	120	

7. Mill (southern end of village).

Well 20 ft., the rest bored.

Gravel	4	30 ft.
Blue [Boulder] clay, with chalk-stones ...	26	

8. Rectory Yard.

Red loam 18 ft.

According to *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 630, at the well at the farm by the rectory the level of the curb is 296·13 ft. above Ordnance Datum; the level of the water in February, 1893, was 276·29, and in March 271·13.

Walkern, cont.

9. Walkern Hall.

Clay and Stone [Boulder Clay] 30 ft.

Very variable supply. In dry seasons about 3 ft. of water in the well, rising to 14 in times of much rain. Soaks in all round.

10. Walkern Hall. Gardens.

Water came in quickly, to 3 ft. from the top.
Clay and Stone [Boulder Clay], to sand 19½ ft.

11. Walkern Hall Lodge, about half-a-mile westward of the Hall.

Water said to stand 10 ft. in the well all the year round.

Clay, bricked	5	150 ft.
Chalk	145	

12. Yew Tree Inn.

Yellow sand, 27 ft.

There are many other wells in Walkern, but from want of precise sites, in the notes, and from slightness of information, they are not now noticed. Several go through clay to sand.

R. E. Middleton says:—"It is evident that most if not all the wells in Walkern are very much affected by surface water, and that many if not all of them, with the exception of two—Mr. Wright's and the brewery well—have no connection with the chalk water system." *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 631. But others than those mentioned go to a considerable depth in the Chalk.

Ware.

Ordnance Maps 239, 240, new ser. (Herts. 29, E., 30 W.). Geologic Map 47.

1. Blakesware. A park ENE. of the town, close to Widford.

A four-inch boring, made and communicated by Messrs. A. Williams and Co. Water-level 98 ft. down.

Yield 300 gallons an hour, with hand-pump.

		Thickness. Ft.	Depth. Ft.
[Glacial Drift]	Blue gault [Boulder Clay] .	8	—
	Very hard ballast [gravel] .	10	—
	Loamy brown sand and clay	2	—
	Hard light-coloured sand ..	2	—
	Hard light-coloured gault [Boulder Clay], with layer of stone	8	30
[Upper] Chalk and flints		94	124

2. Broadmead Pumping Station of the Metropolitan Water Board. About ¼ mile NE. of Chadwell Spring. 1879.

Ground-level 110·29 ft. above Ordnance Datum.

A. J. Jukes-Browne. *Quart. Journ. Geol. Soc.* 1894, vol. l, pp. 501–507 (from specimens).

Well 26 ft., the rest bored.

Level of water given, in 1896, as 106·71 ft. above Ordnance Datum. J. M. Wood states that on 30th April, 1919 it was 110·27, or practically level with the surface. This was after a heavy flood.

Yield 1,500,000 gallons a day.

		Thickness. Ft.	Depth. Ft.
Alluvium		17	17
River Drift			
Upper Chalk	Soft white chalk at 116 ft. (resembles chalk from zone of *Micraster cortestudinarium*); at 145 and 149 ft. (with streak of grey marl); and at 160 and 172 ft.	183 ?	200
	Firm rather tough chalk, with many streaks of grey marly material, at 174 and 178 ft.		

Ware, cont.

		Thickness. Ft.	Depth. Ft.
Middle Chalk	Rather hard white chalk at 211 and 212ft. Soft white chalk at 231 and 246 ft. ... Firm white chalk at 287 and 340 ft. ... Rather hard white chalk, with the usual characters of the *Terebratulina gracilis* zone, at 387 ft. ... ... Hard creamy white chalk at 411 ft. It clearly comes from the zone of *Inoceramus mytiloides*. ... ... Very hard creamy white chalk, like the more solid parts of the Melbourn Rock, at 423 and 427 ft.	227	427
Lower Chalk	Soft greyish marly chalk, resembling that of the *Belemnitella plena* zone, at 430 ft. Firm greyish-white chalk at 443 (rather hard), 470, 476 and 500 ft. ... ... Soft grey chalk at 510, 511 and 512 ft. Rather hard grey chalk at 517 and 520 ft. Rather hard grey Chalk Marl at 530, 550, 556 and 558 ft. ... ... Firm grey Chalk Marl at 569 and 579 ft. glauconite-grains common	163	590
Upper Greensand.	Rather hard grey sandy micaceous chalk; minute glauconite-grains, at 585 ft. ... Greenish, sandy, glauconite and micaceous marl at 587 and 588 ft. ... Label lost, but apparently from 590 ft. Dark grey sandy marl, with two phosphatic nodules *Pecten interstriatus, P. orbicularis* and *Inoceramus* [the bottom bed of the Chalk Marl] ... ... Fine grained, grey, marly, glauconitic and micaceous sandstones (with phosphatic nodule at 592) at 591, 592 and 604 ft. ... ... Lighter-coloured, glauconitic, micaceous sandstone at 613 ft. (a sponge-bed) ... Light-coloured siliceous stone at 621 ft., almost entirely colloid silica ... ... Calcareo-siliceous rocks, like calcareous malmstone, at 622 and 628 ft. ...	40	630
Gault	Fine dark-grey silty clay at 632 ft. ... Dark-grey clay, somewhat calcareous, at 658 ft. ... ... Nine samples of dark grey clays, 670 to 725 ft. ... ... Fine compact dark-grey clay at 790 ft. Dark, dull-green sand, held together by earthy matter: glauconite grains at 796 ft.	166½	796½
Wenlock Beds	Grey shelly limestone (*Leptæna transversalis, etc.*) at 800 ft. ... ... Dark-grey earthy mudstone, with a shelly layer (*Leptæna transversalis, Pentamerus linguifer? Orthis elegantula*, etc.) at 802 ft. ... ... Hard, earthy mudstones, slightly calcareous, with shelly layers (*Leptæna* and *Orthis*) at 804 and 809 ft. ... ... Dark grey calcareous sandstone, with many fossils (*Pentamerus galeatus*) *Orthis elegantula*) at 827 ft.	35	831½

Ware, cont.

In the old accounts too great a thickness (77 ft.) was given to the Upper Greensand, chiefly at the expense of the Chalk, then given as 544 ft., instead of 573 as now. A sandy bed at the base of the Gault (1½ ft.) has been classed as Lower Greensand; but this is an error.

A fine core of the Wenlock Beds is to be seen in the Museum at Jermyn Street. According to J. Francis (*Brit. Assoc.*, 1895, p. 451) the dip of these beds at the depth of 828 ft. is in a direction about a degree west of south and at an angle of 41 degrees.

3. Mr. Clark's. Made and communicated by Messrs. Le Grand and Sutcliff. Water-level 74½ ft. down.

		Thickness. Ft.	Depth. Ft.
Dug well (the rest bored)		—	4
[Drift] ...	Clay and stone	13	—
	Flints	¾	—
	Clay and flints	2	—
	Clay mixture	9¾	—
	Clay	7	—
	Clay and pebbles	8½	—
	Gravel	13	58
Chalk		54	112

4. Little Fanhams Hall Farm, on the northern slope of valley, a mile south of Thundridge Church. 1878.

About 197 ft. above Ordnance Datum. Tube-well.

Communicated by R. G. Austin, Hertford.

Water, from the Chalk, rose to about 72 ft. from the surface.

		Ft.
? Soil		3½
[Glacial Drift]	Boulder clay with chalk particles	28½
	Brown sand, with bad water, which rose to the surface	1
	Hard clay and pebbles [? Boulder clay]	12½
	Yellow gravel, coarse and loamy	14½
	To chalk	60
Dry clayey chalk and flints (water struck at 90 ft., and rose 18 ft.) ... ... about		30
Chalk and flints ... ... „		22
		112

An old well at Fanham Hall is said to be 120 to 130 ft. deep.

The Windmill-pump (? of first well) is 300 yards north-east of the Hall.

5. Smallpox Hospital.

Made and communicated by Messrs. A. Williams and Co.

Shaft 8 ft., the rest bored.

Water rose to within 80 ft. of the surface.

		Thickness. Ft.	Depth. Ft.
[Drift] ...	Ballast [gravel]	17	—
	Sand and ballast	8	—
	Ballast and chalk	12	37
[Upper Chalk]	Grey chalk	13	—
	Chalk and flints	100	150

6. Waterworks. Musley Hill, east side of road, north-east of the Workhouse. 1870.

Communicated (originally) by Messrs. Russ and Minns; but mainly from later information from various sources on the spot from H. F. Hill (the Surveyor), etc.

Engine-room-floor 213·72 ft. above Ordnance Datum.

Shaft of 6 ft. diameter, about 130 ft., then a 12-inch boring.

Headings. One 4 by 4 ft., 40 ft. long, NE. Water comes out in it, from soft places in the Chalk, in rings about 5 ft. apart. The works started with the

Ware, cont.

supply from this. It was found inadequate and a second heading was driven NW., of large size to start with, 8 ft. high by 6 ft. broad, getting smaller as it goes on: it is about 80 ft. long, and at 40 ft. from the well a break in the bottom and some flints on the northern side gave out water that doubled the supply. These two headings may be said to give the supply as practically nothing comes from the well or boring.

At first and for some time the water rose in the well, from the headings, about 32 ft. Later the level lowered. The water-level was originally given as about 100 ft. Mr. HILL says (1916) that this is the highest rest-level.

Gravel, etc.	about 30	160 ft.
[Upper] Chalk	„ 130	

From *R. Comm. Metrop. Water Supply. Appendices.* 1893, p. 521.

"When the well was made, about 18 years ago, the yield was about 180,000 gallons per day of 24 hours, and the water rose 48 to 50 ft. from the bottom (given as about 140), but the yield is now reduced to between 150,000 and 160,000 gallons per day, and the water rises to about 31 ft. only from the bottom. This loss is mainly attributed to the abstraction of water from the chalk by the New River Company," which has four pumping stations within two miles of the town. On p. 612 the original yield is given as 70,000 gallons a day and that of 1892 (?) as about 130,000. H. F. HILL gives the yield as about 100,000 gallons a day in 1916.

It is added (p. 522) that the water-levels in "the wells in the town and the immediate neighbourhood are generally much lower than formerly."

See also p. 103 of this Memoir.

7. Waterworks, newer, Musley Lane (southern side, opposite Trinity Road), SE. of the Workhouse. 1896.

From H. F. HILL, Surveyor to the Council.

Engine-room-floor-level 129·7 ft. above Ordnance Datum.

Shaft, of 7 ft. diameter, for 61 ft., and then a 30-in. boring to the depth of 100 ft.

Highest water-level 25 ft. down.

Yield about 104,000 gallons a day.

To Chalk, below the level of the engine-room-floor, 27 ft. 10 in.

Chalk 73 ft.

The Local Government Board Return of 1915, p. 148, says:—"The average daily quantity of water obtained is 160,000 gallons" (from the two wells) and more could be got. The quality is satisfactory. Furnishes a supply in bulk to Ware Rural District Council.

For analysis of the waters from the two wells, *see* p. 329.

Ware was, and perhaps still is, an exceptional place in the matter of water-supply, for the largest demand comes in the winter-months. The reason is that the manufacture of malt is the staple industry, and that needs water in the winter-season.

Ware, Rural. Maps as for Ware.

Information from Dr. R. L. SHERLOCK.

Wells on the Poles Estate. (*See also* under *Thundridge.*)

a. Lodge 750 yards SE. of the house. 220 ft. above Ordnance Datum. Well about 118 ft. deep, with 6 to 7 ft. of water. Gravel and clay, 50 ft., on Chalk.

b. Watton Road Lodge, 1,000 yards WSW. of the house, about 246 ft. above Ordnance Datum. Well about 107 ft. deep, with 7 ft. of water. 5 ft. of soil over Chalk.

c. Vicarage, 950 yards SSE. of the house, 200 ft. above Ordnance Datum, disused. Well 106 to 108 ft. deep, with about 8 ft. of water. About 60 ft. of gravel, bricked, over Chalk.

Ware Park. At the house. Well about 110 ft. deep, with about 10 ft. of water.

Watford.

Ordnance Maps 255, 256, new ser. (Herts. 39, SW. 44, NW.). Geologic Map 7.

1. Cannon Brewery, Benskin and Co. On the western side of High Street, just northward of the new waterworks. 1867? Deepened later. 195·58 ft. above Ordnance Datum.

Made and communicated by R. B. Paten (original well).

Shaft 25 ft., the rest bored.

Average number of gallons pumped in 24 hours, 124,188 (1892).

Clay and gravel	25	215 ft.
[Upper] Chalk and flints	190	

A newer well, 195·43 ft. (? 215) above Ordnance Datum.

Made and communicated by Messrs. Le Grand and Sutcliff (1894) and from Messrs. Benskin.

Cylinders, of 8 ft. diameter, to 70 ft. Then a 16-inch boring to 530 ft. Then a 12-inch boring to 710.

Rest-water-level about 31 ft. down.

Point of largest supply 510 ft. down. Yield 656,000 gallons a day.

		Thickness. Ft.	Depth. Ft.
Soil		8	8
[Upper Chalk]	Hard chalk and flints ...	144	—
	Soft chalk	20	—
	Chalk and flints	20	—
	Hard grey chalk rock ...	3	—
	Soft chalk	2	—
	Very hard chalk (7) and hard chalk rock (14) ...	21	—
	Soft blue clay	2	—
	Hard grey chalk rock ...	14	234
[? Middle Chalk.]	Hard chalk, with layers of soft chalk	225	—
	Blue clay [? Belemnite Marl]	?	462
[? Lower Chalk]	Very hard chalk	239	701
Upper Greensand		6	707
Gault		8	715

2. Eastbury. Pumping Station of the Colne Valley Water Co. On the northern side of Hamper Mill Lane, a quarter of a mile east-north-east of Hamper Mills and south-south-west of Oxhey Hall.

Communicated by the Co.

179·35 ft. above Ordnance Datum.

Well of 10 ft. diameter.

Standing level of water 23 ft. down. No continuous use having been made of this station the effect of pumping cannot be given.

Clay, gravel and sand	50	200 ft.
[Upper] Chalk	150	

3. Leavesden Asylum, a little east of Abbots Langley. 1870.

363·2 ft. above Ordnance Datum.

Report of Meeting of Managers of Metropolitan Asylum District, 29 January, 1887, p. 1016.

Shaft 225 ft., steined for 68. At 220 ft. two headings, to north-west 50 ft. long, to south-south-west 32 ft.: in the former, at 38 ft. from the well, a very strong spring (5/6ths of the supply; the rest being from a small spring in the shaft and from flint beds). Total yield not over 5,000 gallons an hour.

[Upper Chalk].	Marl [= rubbly or decomposed Chalk], 20 or 30 ft. Then Chalk struck on one side, whilst on the other the marl went down to 65 ft., when the main body of the Chalk was reached. Chalk. Below 68 ft. there are narrow bands of flat flints at irregular intervals, 4 to 12 ft. apart. The chalk is much disturbed, beds of flints in one or two instances being diverted to a nearly vertical position.

Watford, cont.

"A former attempt which has been made to increase the supply by boring from the bottom of the well in the hope of reaching the greensand, failed, the gault having been unexpectedly encountered. The result was that the water drained through the bore-hole, and the latter had to be plugged in order to preserve the existing supply." Without further details this statement is hard to understand, and it seems unlikely that Gault was really reached. However, R. E. MIDDLETON notes, from a Report of 1869, that the well is 228 ft. deep and then that there is a boring of 378 ft. (= 606 total), whilst another Report makes the total 610.

A communication from the Board in June, 1911, gives the following particulars. Yield of each boring (? heading) 7,000 gallons an hour. Water-level before pumping is started 145 ft. down, and after 4 hours' pumping 160 ft. down. There is a difference of level in winter and summer of from 5 to 6 ft.

According to U. A. SMITH (*R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 398) between 1879 and 1881 the water-level was reduced nearly 10 ft. ; and a further fall of 7 ft. occurred between 1881 and 1891. In 1887 a new heading was driven. "More springs were tapped, but the level of the water did not rise. This well is very quickly affected by rainfall. Some 20 years back (? about 1873) the rate of daily consumption was about 150,000 gallons, but it is now (1893 ?) only between 70,000 and 80,000." R. E. MIDDLETON says that the recorded fluctuations correspond with the meteorologic evidence. *Ibid.*, p. 356, and he gives a record of the variations of the rest-level from 1879 to 1886 and in 1892.

4. Leavesden. Coles Farm.

Communicated by H. S. NUNN.

Bricked for 30 ft., and as it is a very old well no information can be given as to this part.

Below the well (100 ft. deep) is in firm chalk, with a few large flints.

The natural water-level seemed to be 97 ft. down, and the water was exhausted after pumping 40 or 50 gallons.

A six-inch bore-hole was made and a bed of hard chalk-rock was found 174 to 175½ ft. down, and the boring was continued in less firm chalk.

With the suction-pipe down the bore-hole, to the depth of 115 ft., a test of 4 hours' pumping yielded from 220 to 230 gallons an hour and made no perceptible difference in the water-level.

5. Leavesden. St. Pancras Schools.

350·77 ft. above Ordnance Datum.

Information from J. SMALES.

Water-level 125 ft. down.

40,000 gallons an hour pumped, for 9 hours a day.

Well of 7 ft. diameter all in Chalk, 250 ft.

U. A. SMITH says (*R. Comm. Metrop. Water Supply. Appendices.* 1893, p. 308) "Formerly there was about 133 ft. of water in this well, but this quantity gradually decreased until in August, 1892, there was only 123 ft. of water."

For an analysis of the water, *see* p. 329.

6. Lion Brewery, Wells and Co., St. Albans Road.

Made and communicated by S. F. BAKER and SONS.

Found water at 53, 70, 105 and 119 ft. down.

Made ground	½	
[Glacial Gravel]. Rough ballast	10½	127 ft.
[Upper] Chalk, with flints very close together down to 85 ft., and from 3 to 12 in. thick. Below that further apart	116	

7. London and North Western Railway. On the western side of the line between Watford and Bushey Stations.

Sunk and communicated by R. B. PATEN, with further information from F. W. WEBB, *R. Comm. Metrop. Water Supply.* 1893. *Appendices*, p. 573.

179·4 ft. above Ordnance Datum.

Shaft, of 12 ft. diameter, 36 ft., and two borings of 11 in. diameter.

Watford, cont.

Pumping night and day. When the well is at rest for a time the water rises to within about 6 ft. from the surface and is reduced by regular pumping to about 3 ft. from the bottom [of the well].

Loose earth	1		
[River Drift] Running gravel	11	266 ft.	
[Upper] Chalk, flints and rock-chalk ...	254		

8. London and North Western Railway Station.

Made and communicated by R. B. Paten.

Surface earth	2		
[Glacial Drift] Yellow clay	8	195 ft.	
[Glacial Drift] Gravel	2		
[Upper] Chalk	183		

In 1892 F. W. Webb reported that this well was covered over and not in use. For an analysis of the water, *see* p. 330.

9. London Orphan Asylum. Eastward of the Railway Station.

About 190 ft. above Ordnance Datum.

Made and communicated by R. B. Paten.

Shaft 51 ½ ft., the rest bored.

Water rose to within 52 ft. of the surface. Yield about 80,000 gallons a day (according to "A Treatise on Waterworks" by S. Hughes, new Ed. 1875, p. 217).

		Thickness. Ft.	Depth. Ft.
[Drift] ...	Brown clay	12 ½	—
	Gravel	19 ½	32
[Drift or Reading Beds?]	Sand	18	—
	Flints	1 ½	51 ½
Chalk with flints		255 ½	307

10. Oxhey. Southward of the town.

Made and communicated by R. B. Paten.

Shaft 126 ft., the rest bored.

[London Clay ? and Reading Beds] Clay, gravel and sand	60	286 ft.
[Upper] Chalk, with flints	226	

11. Paget Prize Plate Co. St. Albans Road, next Wells's Brewery.

From A. C. G. Cameron's Notes.

Water-level 41 ft. down.

[Glacial] gravel	7	120 ft.
[Upper] Chalk and flint	113	

A note of a boring made and communicated by Messrs. Isler and Co., 1914 differs, as follows, and gives other information.

Boring of, 8 ¼ in. diameter, with 30 ft. of tube. Starting water-level 44 ft. down.

Clay and Flints	29	151 ½ ft.
[Upper] Chalk	122 ½	

12. Sedgwick and Co.'s Brewery. On the eastern side of High Street, near Waterworks. 1874.

Over 182 ft. above Ordnance Datum.

Made and communicated by R. B. Paten.

Shaft 5 ft. 2 in., the rest bored.

Loose [Glacial] gravel	10	233 ft.
[Upper] Chalk, with flints	223	

According to U. A. Smith, *R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 398, there are two wells at this brewery. Formerly the water in the newer well stood at 9 ½ ft. below the floor of the engine-room, and that in the old well 4 ½ ft. below the yard-level. In July (1893 ?) the levels were found to be 19 ¼ ft. and 16 ft. 2 in.

Watford, cont.

13. Tolpits (Twopits of the old map). Just north of the Colne, about two miles south-westward of the town.

Made and communicated by R. B. Paten.

Shaft 15 ft., the rest bored.

[Glacial] gravel	...	...	...	...	15	135 ft.
[Upper] Chalk and flints	...	...	...	...	120	

14. Waterworks. Established 1854.

The old works are on the western side of the High Street at the southern end of the town. Three wells. Information chiefly from D. Waterhouse, Engineer to the Council.

No. 1. Outside the engine-house, at its northern corner. 1854. 179.39 ft. above Ordnance Datum. 6 ft. diameter for 39½ ft.; lined with cast-iron cylinders; then a 12 in. boring, lined for 27 ft. Depth 115¾ ft.

No. 2. About 50 ft. north-westward of No. 1 (and at slightly higher level, 1881. A nine inch boring 150 ft. deep.

No. 3. At the northern corner of the ground, about 160 ft. north-westward of No. 1. 1888. 186·71 ft. above Ordnance Datum. ? cylinders of 6 ft. diameter for 40 ft. An 18 in. boring to 140½ ft.

Water syphoned from 2 and 3 into 1. Approximate yield (? 1899) 800,000 gallons a day.

According to R. E. Middleton (*R. Comm. Metrop. Water Supply. Appendices*, 1893, p. 601. On 11th August, 1892, the rest-level was 167·06 ft. above Ordnance Datum, pumped down to 157·06.

The following account, made and communicated by Messrs. Le Grand and Sutcliff (published 1889), may refer to No. 2, the level given being 178¾ ft.

Water-level 11½ ft. down; lowered 3 ft. by pumping at the rate of 6,000 gallons an hour. Estimated supply, with pumps at the surface, 33,000 gallons.

[Drift] ...	Well (the rest bored), presumably in gravel	...	8½	151 ft.	
	Gravel	...	...	12½	
	Chalky gravel	...	...	4½	
[Upper] Chalk and flints	...	...	...	125½	

Of course the other two wells are also in the Chalk.

The new works are a little westward of the old ones, on the southern side of the recreation-ground, 1914 ?

Information from D. Waterhouse, with whom I had the pleasure of seeing the works.

In the engine-house there are four bored wells, of 3 ft. diameter, lined to 78 ft. with cast iron tubes of 40 in. internal diameter (therefore this top part must be larger). All to the depth of 350 ft. in the Chalk.

About 30 ft. south-eastward from the wall of the engine-house is a well of 6 ft. diameter, lined to the depth of 79 ft. with cast-iron cylinders of 78 in. internal diameter (therefore the top part must be larger), to the depth of 300 ft. in the Chalk. This is about 190 ft. above Ordnance Datum.

About 45 ft. northward from the northern corner of the engine-house is an Auxiliary Well, a boring of 30 in. diameter, lined to 81 ft. 5 in., and carried to a depth of 257¾ ft. below the floor of the temporary engine-house.

According to the Local Government Board Return of 1915, p. 150:—"The average daily quantity of water obtained (at the Watford Works) is 1,199,360 gallons . . . the water is excellent." For analysis, *see* p. 330.

The accounts of the following Watford wells (15 to 20) are from U. A. Smith's Statement, *R. Comm. Metrop. Water Supply. Appendices*, 1893, pp. 397, 398.

15. Cassiobury Saw Mills. 234·42 ft. above Ordnance Datum. Well 54 ft. deep. Some five years back contained a depth of 16 ft. of water. In August, 1892, this depth was 12 ft., 1,800 gallons a day drawn (Middleton).

16. Colnehurst. A third of the way from the junction of Langley Road and Church Road to Nascot Wood. Not now used (J. Hopkinson). 274·74 ft. above Ordnance Datum. 94 ft. deep. Deepened 4 ft. in the latter part of 1890, having run dry.

Watford, cont.

17. Gammons Farm. On the eastern side of the railway-tunnel, north-north-west of the town. 326·59 ft. above Ordnance Datum. Well 130 ft.. Deepened some few years back, on account of insufficiency of supply.

18. King Street Brewery, Healey's. Disused. 230·14 ft. above Ordnance Datum. Water-level 55 ft. down, has been reduced permanently 4 to 5 ft. Well 60 ft. Boring to 211.

19. Tunnel Woods. Halfway between Callowland Spring and Nascot Wood, just opposite the mouth of the railway-tunnel (J. HOPKINSON), 1890. Lowered 3 ft. in 1891. 281·69 ft. above Ordnance Datum. 84 ft. deep. R. E. MIDDLETON says that the seasonal difference is enough to account for the lowering of the water-level (*ibid.*, p. 556).

20. Watford Union. 237·18 ft. above Ordnance Datum. Between 1886 and 1889 the water-level decreased 4 ft. It is now (1893) about 100 ft. down.

Watton at Stone.

Ordnance Maps 221, 239, new ser. (Herts. 21, SW.). Geologic Map 46, SE.

1. Blue Hill, a mile north-westward of the Church.

Information got by A. C. G. CAMERON from Mr. ALRIDGE, well-sinker.

Glacial Drift	(Boulder Clay). Blue clay with chalk-stones ...	40	66 ft.
	Coarse gravel	7	
	Concrete (cemented Drift), to get through which took seven days	4	
	Gravel and a deposit like wood-ashes	15	

2. Woodhall Park.

Made and communicated by A. WILLIAMS and Co.

Water-level 180 ft. down. In January, 1909, 181 ft.
Yield 1,500 gallons an hour.

		Thickness. Ft.	Depth. Ft.
Loamy sand		25	—
Mottled sands		25	50
[Upper Chalk]	Chalk and flints	254	—
	Flints	2½	—
	Chalk and flints	33½	340

Welwyn.

Ordnance Map 239, new ser. (Herts. 28, NE.). Geologic Map 46, SE.

Information got by A. C. G. CAMERON.

1. Danes Bury. Shaft.

Heavy clay	15	150 ft.
Chalk...	135	

2. Gas Works. Plenty of good water, which was pumped to the Frythe, 400 yards westward.
Gravel to Chalk, 30 ft.

3. Mill Cottages. On the Hertford road.

Shaft, through clayey gravel and clay ...	30	50 ft.
Bored in Chalk	20	

4. Waterworks. Welwyn Rural District Council (? at Church Fields Cottages, Lower Green),
Local Government Board Report of 1915, p. 152. (Two wells.)
80 ft. in Chalk (? 20 to Chalk). Average daily quantity 30,000 gallons.
Another well 240 ft. in Chalk at Harmer Green. Average daily quantity 10,000 gallons.
More could be got, especially from the latter well.
Water good. For analysis, see p. 331.
Part of Digswell parish is also supplied.

Welwyn, cont.

The following information on the Harmer Green Well, got from the engineer in charge, by Dr. R. L. Sherlock. Site about 300 yards south-east of the Green. Depth 240 ft., to water 210.

Mostly gravel 30–40 ft., the rest chalk.

5. Workhouse.

A few feet of soil, and then chalk, to 80 ft.

Westmill.

Ordnance Map 221, new ser. (Herts. 14, W.). Geologic Map 47.

Westmill Bury. 1890.

Communicated by G. Ingold, the figures being only approximately correct, as got from the well-sinker.

Shaft 15 ft., the rest bored.

Water 12 ft. down.

		Thickness. Ft.	Depth. Ft.
[Drift] ...	Gravel	16	—
	Yellow clay	10	—
	Grey clay	15	—
	Red sand	2	—
	White chalky clay... ...	10	53
Soft chalk		66	119

Mr. Ingold remarks that this well is in a valley, with the Chalk at the surface at a much higher level on the eastern side; whilst in a well at the school, on the western side, the Chalk is about 20 ft. down. This points to a Drift channel.

Weston.

Ordnance Map 221, new ser. (Herts. 7, SE., 12, NE.). Geologic Map 46, NE.

Information got by A. C. G. Cameron, and from R. E. Middleton (*R. Comm. Metrop. Water Supply. Appendices.* 1893).

1. Lannock Farm, westward of the village.

R. E. Middleton, p. 562.

Water-level in March last (? 1892) 273·6 ft. above Ordnance Datum; "there was 35 ft. of water in the well, and it had never been dry."

2. Live and Let Live Inn. (From the occupier.)

Tough clay	6	7 ft.
Silver sand and water	1	

3. Public Supply.

Local Government Board Return of 1915, p. 279.

M. R. Pryor supplies the parish from a "Well, 234 ft., in Lower Chalk, near Darnall's Hall. . . . The average daily quantity of water obtained is 4,500 gallons," and more could be got. Quality excellent.

4. Town Farm.

Deepened in 1891. Level of Curb 418·15 ft. above Ordnance Datum, 220 ft. deep. Water-level in March (1892?) 293·15 ft. above Ordnance Datum, (R. E. Middleton, p. 625.)

5. White Horse Inn. (From the occupier.)

Boulder clay	Light-coloured clay	4	17 ft.
	Tough blue clay with gravel veins ...	13	

6. Windmill, westward of the village. Chalk, with flint and sand-veins. 170 ft.

This well fell in in 1889, owing it is said to the sand causing subsidence on the water being drawn from it. According to R. E. Middleton (p. 625), the level of the curb is 442·12 ft. above Ordnance Datum and the depth to water 305·62.

Other wells in and near Weston are noted by Middleton.

Wheathampstead.

Ordnance Map 239, new ser. (Herts. 28, W.). Geologic Map 46, SE.

1. Brewery. (? Hope Brewery.)

Noted by A. C. G. Cameron.

Water stood 16 ft. in the well and the yield was about 150 barrels a week.

Gravelly soil	8 to 10	? 120 ft.
Chalk	110	

At the bottom there is stone (? Chalk Rock).

Many other wells were noted by Cameron; but the information about them is too vague to be used.

2. Nursery, 500 yards south-south-west of Marford. Well said to pass through 90 ft. of Drift (Boulder Clay and Gravel) and 10 ft. of Chalk. From Dr. R. L. Sherlock.

R. E. Middleton says of a well at Marford "When other wells were dry two years ago this well, which is 50 years old at least, contained plenty of water; while another well on the other side of the road was deepened in 1891." *R. Comm. Metrop. Water Supply. Appendices.* 1893, p. 559.

Widford.

Ordnance Map 240, new ser. (Herts. 30, NE.). Geologic Map 47.

1. Mr. Parkes' Cottages, 1899.

Made and communicated by G. Ingold.

	Thickness. Ft.
Soil	1
Brown clay	8
Gravel and sand	2
Brown clay	6
Gravel	2
Brown clay	11
Blue clay	15
Hussock	5
Blue clay	13
Sand	7
Gravel	11
Loamy sand	4
Grey sandy clay	3½
Grey sand	2½
Brown clay	1
	92

2. Mr. Wiseman's Cottages. 1878.

Made and communicated by G. Ingold.

Soil	3	108½ ft.
White clay	22	
Blue clay	15	
Brown clay	1	
Sand and gravel	2	
Brown clay	2	
Sandy loam	7	
Gravel	6	
Brown clay	2	
Black sand	4	
Pebbles	2	
Brown loam	5	
Grey sand	23	
Chalk	14½	

Widford, cont.

3. Winters. Two wells. 1893.

Made and communicated by C. Ingold.

No. 1, Very little water.

Yellow Boulder Clay	5	
White Boulder Clay	9	45 ft.
Blue Boulder Clay, to sand	31	

No. 2, 24 ft. deep in Boulder Clay, yielded 30 gallons an hour.

4. Nether Hall.

Well 4½ ft. diameter, 100 ft. deep.

Water-level 90 ft. down. Supply 400 gallons an hour.

Wigginton.

Ordnance Map 238, new ser. (Herts. 25, SE.). Geologic Map 46, SW.

Chiltern Hills Water Co. Just south-west of Newground Farm and about 1,250 yards east-north-east from the church.

? about 425 ft. above Ordnance Datum.

Wells 93 ft. deep. First boring to 200 ft., of 18 in. and then of 9 in. diameter. Second to 158½ ft., of 20 in. diameter.

Water pumped down to 19 ft. above the bottom of the wells. Rises 13 ft. on ceasing pumping.

Average daily yield 347,000 gallons (Local Government Board Return of 1915).

Gravel, 25 ft. or more.

Chalk. Specimens from the second boring mostly clayey, especially in the lower part; at bottom (3 specimens) a gritty impure chalk. 175 ft. or less.

Wormley.

Ordnance Map 239, new ser. (Herts. 36, SE.). Geologic Map 1, NW.

West End. For Mr. G. F. Bosanquet.

B. Latham. *Trans. Soc. Eng.* for 1864, p. 249 and pl. 5.

Shaft 85 ft. (of 4 ft. diameter for 38 ft., when it widens and at 50 ft. is 6 ft. diameter to 70 ft., then 3¾: steined with brick), the rest bored. Water rose to within 62 ft. of the surface.

		Thickness. Ft.	Depth. Ft.
Surface-earth		1	1
Loam [River Drift ?]		9	10
[London Clay, 22 ft.]	Yellow clay	10	—
	Blue clay	12	32
[Reading Beds, (and Thanet Sand ?) 40 ft.]	Brown sand	6	—
	White sand with pebbles ..	14	—
	Brown sand with water ...	20	72
Chalk		63½	135½

3. Wormley End (Sir A. Home's).

Conybeare and Phillips, *Geology of England and Wales*, 1822, p. 41.

Chalk found 100 ft. down.

Wymondley, Little.

Ordnance Map 221, new ser. (Herts. 12, N.). Geologic Maps 46, NE. and SE.

1. House in the village, 200 yards west of the railway, bridge (over the road) to Stevenage).

W. Hill, *Proc. Geol. Assoc.*, 1912, vol. xxiii, p. 219.

247 ft. above Ordnance Datum. A boring.

Wymondley, cont.

		Thickness. Ft.	Depth. Ft.
Soil and made earth		1	1
Glacial Drift.	Gravel	9	—
	Bright yellow loam ...	8	—
	Gravel	3	—
	Sand	14	—
	Blue Boulder Clay ...	15	—
	Very chalky Drift ...	40	—
	Loose gravel and stones ...	1	—
	Very chalky Drift ...	14	105
Solid [Middle] Chalk		10	115

The chalky Drift looked so white and clean when brought up by the auger that it was at first mistaken for Chalk.

2. Wymondley Bury Farm. Just south of the church.

Same authority. A boring.

About 300 ft. above Ordnance Datum.

Soil		3	
Glacial Drift.	Red stoney clay	19	110½ ft.
	Sand with large stones ...	33	
	Blue Boulder Clay ...	14½	
	Red-brown sandy gravel ...	21	
	Chalk rubble	20	

The chalky rubble was probably of the same character as that at the bottom of the other boring, but was not seen by Mr. HILL.

Yardeley, *see* **Ardeley.**

ANALYSES OF SPRING-WATERS.

BUCKINGHAMSHIRE.

Brickhill, Great.

Water from Lower Greensand. Soft.

W. W. FISHER, *Analyst*, July, 1902. In grains per gallon.

Total solids	14·
Chlorine in chlorides	1·2
Nitrogen in nitrates	·497
Saline ammonia	·003
Albuminoid ammonia	·001
Oxygen absorbed in 3 hours	·014

Brill.

1. Below (and about 340 yards south of) Waterloo House.

2. Below main road to Thame, about 250 [? 500] yards from Brill Green.

3. Thame Road Spring (? nearly three-quarters of a mile a little west of south from the church).

All from Portland Stone. *See* p. 45.

Made by Dr. CHARLES COLES. Nos. 1 and 2 March, 1905, No. 3, Nov., 1904. Communicated by Mr. PARRY, Surveyor to Long Crendon Rural District Council.

	In parts per 100,000.		
	No. 1.	No. 2.	No. 3.
Total solid matter	56·	98·	54·
Chlorine	3·9	8·6	2·3
(Equal to common salt)	6·4	14·1	3·7
Nitrates	Nil.	Nil.	Nil.
Nitrates expressed as Nitrogen ...	1·85	4·55	1·28
Ammonia, Free	·002	·001	·003
Ammonia, Albuminoid	·001	·01	·008

The nitrates (in No. 3 and presumably in 1 and 2) are high but this may be due (Mr. PARRY suggests) to the proximity of allotments and not to the Brill sewer, which is half a mile away (from No. 3) and separated by a valley.

Buckingham.

Two analyses. By W. W. FISHER, February, 1888. In Dr. H. F. PARSONS's Report to Local Government Board, No. 25, pp. 9, 10. *See* p. 97.

1. Spring in Field [? feeding Bath Lane spout]. Bright, but slightly turbid owing to particles of floating matter, apparently mineral. Residue left on evaporation nearly white. In two-foot tube, bluish tint, good colour.

2. Public Supply, Bath Lane. Slightly turbid; some floating particles of vegetable tissue. Residue on evaporation nearly white, with only a trace of brown organic matter. In two-foot tube, bluish tint, good colour.

	In grains, per gallon.	
	1	2
Total dissolved solid matter	35·	37·5
Chlorine in chlorides	1·	1·1
Ammonia, free and saline	·006	·006
Ammonia, albuminoid	·005	·005
Nitrogen as nitrates	·07	·07
Nitrogen as nitrites	0	0
Oxygen required to oxidise organic matter in 3 hours	0	0
Total hardness	31·	31·
Hardness after boiling	9·4	—

1. Contains more than the usual amount of dissolved solid matter, but the chlorides and nitrates are normal in quantity. Contains a very small amount of organic matter. The dissolved matter largely consists of carbonate of lime. A pure natural water fit for general use. 2 almost identical with 1.

Charndon.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 32.

	In grains per gallon.
Total solids	145.
Chlorine in chlorides	7·
Nitrogen in nitrates	·07
Saline ammonia	·127
Albuminoid ammonia	·032
Oxygen absorbed in 3 hours	·221

Much sulphate of lime.

Dorton.

Chalybeate Spa, *see* p. 66.

For an old analysis by Prof. Brande, *see* p. 67.

Detailed analysis, made (October, 1909) and communicated by W. W. Fisher.

	In grains per gallon.
Sodium chloride	6·42
Sodium sulphate	27·4
Magnesium sulphate	18·75
Calcium sulphate...	165·36
Ferrous sulphate	4·25
Ferrous carbonate	10·49
Total	232·67

He also adds these particulars :—

Ammonia	·392
Albuminoid ammonia	·008
Nitrogen as nitrates	·01
Oxygen absorbed in 3 hours, from permanganate	·032

Marston, North.

Selborne Spring. *See* p. 113.

By Dr. Bernays. 1868.

	In parts, per 100,000.
Deposited on boiling—	
Carbonate of lime	30·7
Magnesia	Trace.
Iron	Trace.
In solution—	
Chlorine	20·76
Sulphuric acid	13·54
Silica	1·8
Lime	1·42
Magnesia	9·
Total solids	108·1

Preston Bissett.

Ordnance Map 219, new ser. Geologic Map 45, NE. Cowley Hills.

Made and communicated by Dr. J. C. Thresh. September, 1897.

Sandy deposit. Clear. Almost colourless. Very hard, but good.

	In parts per 100,000.
Chlorine	1·3
Equivalent to chlorides	2·2
Nitric nitrogen	·03
Equivalent to nitrates	·18
Nitrites	Nil.
Iron	Trace.
Free ammonia	·004
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C. ...	·17

Hardness, 34·3°.

Quainton. *See* p. 113.

Water from Portland Beds. Hard.

W. W. Fisher, *Analyst.* July, 1902.

	In grains per gallon.
Total solids	27·2
Chlorine in chlorides	1·
Nitrogen in nitrates	·448
Saline ammonia	·001
Albuminoid ammonia	·003
Oxygen absorbed in 3 hours	0
Hardness	22·6

Stoke Goldington.

Public Supply. Spring from Oolitic limestone. *See* p. 114.

Drawn from the main. December, 1915.

Made and communicated by Dr. J. C. Thresh.

Clear and bright. Faint green. No odour. Reaction neutral.

In parts per 100,000.

		Probable combinations.	
Ca	16·6 ...	Calcium carbonate	34·1
Mg	1· ...	Calcium sulphate	10·2
Na	·97 ...	Magnesium sulphate	3·
CO_3	20·5 ...	Magnesium chloride	1·5
SO_4	9·6 ...	Sodium chloride	1·5
Cl	2· ...	Sodium nitrate	1·4
NO_3	1· ...	Silica, etc.	3·
		Total solid constituents dried at 180° C.	54·7

Free ammonia	·0024
Organic ammonia	·002
Oxygen absorbed in 3 hours at 37° C. ...	·02
Nitrites	Nil.

Hardness, Temporary, 32°; Permanent, 13°; Total, 45°.

Stowe.

From the Gardens in the park.

Water from Great Oolite by mistake credited to Portland Beds.

W. W. Fisher, *Analyst.* July, 1902.

	In grains per gallon.
Total solids	23·2
Chlorine in chlorides	1·4
Nitrogen in nitrates	·154
Saline ammonia	0
Albuminoid ammonia	·012
Oxygen absorbed in 3 hours	·043
Hardness	18·

Weston Underwood.

Public Supply, Spring Estate. Spring from Jurassic Limestone (*see* p. 114).

From external tap at cottage in High Street. Direct from main. December, 1915.

Made and communicated by Dr. J. C. Thresh.

Clear and bright. Faintly green. No odour. Reaction neutral.

Weston Underwood, cont.

In parts per 100,000.

			Probable combinations.	
Ca	18·4	...	Calcium carbonate	34·3
Mg	1·3	...	Calcium sulphate	14·7
Na	3·6	...	Magnesium sulphate	6.3
Fe	Trace.	...	Sodium chloride	7·
CO_3	20·6	...	Sodium nitrate	3·
SO_4	15·	...	Silica, etc.	2·7
Cl	4·2	...	... ...	—
NO_3	2·2	...	Total solid constituents dried at 180° C.	68·

Free ammonia	·002
Organic ammonia	·0024
Oxygen absorbed in 3 hours at 37° C. ...	·03
Nitrites	Nil.

Hardness, Temporary, 30°; Permanent, 20°; Total, 50°.

Sources from the Lower Oolite.

Made and communicated by W. W. Fisher.

In grains per gallon.

1. Gayhurst. In rear of Gayhurst Cottage (*see* p. 43). From limestone. Hardness 16·8°, total; 9·2° permanent.

2. Turweston. Site doubtful (may be over the border, in Northamptonshire). Mr. Fisher thinks that the water comes from the Lower Oolite near its junction with the Lias.

3. Westbury. The Manor. In the grounds near the house.

	1	2	3
Total solids	39·2	29·68	28·8
Chlorine	1·7	1·3	1·
Free ammonia	·004	·003	·002
Albuminoid ammonia...	·008	·004	·004
Nitrogen in nitrates	·147	·04	·035
Oxygen absorbed	·02	·004	·008

Springs from Drift.

Made and communicated by W. W. Fisher.

In grains per gallon.

1. Calverton. Upper Weald, south-south-east of village. Public Well. Possibly from Cornbrash. Map 219.

2. Soulbury. Liscombe Park. Hop Garden Supply. A good water. Map 220.

3. Wing. Crofton, in grass-field, about 2 miles southward of village. Map 220.

	1	2	3
Total solids	48·	30·5	36·12
Chlorine in chlorides	2·1	1·2	1·9
Free ammonia	·004	·001	·05
Albuminoid ammonia	·006	·004	·006
Nitrogen in nitrates	·02	·02	·03
Oxygen absorbed in 3 hours from permanganate	·02	0	·021

Analyses of the Waters of Buckinghamshire and Hertfordshire Chalk Springs. Sixth Rep. Rivers Pollution Commission, 1874, pp. 123, 127.

In parts per 100,000.

	Temperature Centigrade.	Total Solid Impurity	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
Hughenden, Oct., 1873	11·9	29·9	·024	·013	0	·274	·287	1·4	20·9	3·6	24·5	Clear and palatable.
Wendover Well Head, Aug., 1873 ...	10·8	28·1	·034	·01	0	·369	·379	1·3	19·4	5·7	25·1	Slightly turbid. Palatable.
West Wycombe, Long Meadow Spring, Oct., 1873 ...	10·9	29·86	·038	·005	0	·336	·341	1·4	23·3	4·6	27·9	Clear and palatable.
Aldenham, Otterspool, April, 1868	11	32·36	·026	·012	·002	·422	·436	1·26	21·	3·7	24·7	Clear and palatable.
Amwell, Jan., 1873...	10	28·44	·699	·097	0	·302	·399	1·6	8·4	7·9	16·3	Very turbid.
Amwell, July, 1873	—	33·32	·149	·034	0	·327	·361	1·8	18·4	4·9	23·3	Turbid. Palatable.
Little Amwell, Chadwell Spring, Jan., 1873	10	29·8	·42	·084	·091	·299	·384	1·8	13·4	6·6	20·	Very turbid.

The first four springs are classed as unpolluted, the last two as polluted.

HERTFORDSHIRE.

Aldenham.

Otter Spring, Watford = Otterspool?

R. Comm. Water Supply. Appendix. 1869, p. 104.

(? By FRANKLAND and ODLING.)

	In parts per 100,000.
Total solid residue, dried at 100° C.	32·36
Lime	14·5
Magnesia	·8
Potash	·26
Soda	1·22
Sulphuric acid	·747
Carbonic acid	12·06
Silica	1·67
Chlorine	1·26
Nitrogen as nitrates and nitrites	·422
Ammonia	·002
Organic nitrogen	·012
Organic carbon	·026
Hardness before boiling	24·7
Hardness after boiling	3·7

An older analysis by R. PHILLIPS gives the following particulars, in grains per gallon :—

Carbonate of lime	18·8
Sulphate of lime and common salt	2·5

Also traces of magnesia, silica, oxide of iron, and organic matter.

General Board of Health. Report on the Supply of Water to the Metropolis, 1850, Appendix iii, p. 197.

See also table, p. 274.

Amwell, Little.

Chadwell Spring, *see* pp. 55–61, and table, p. 274.

By W. T. BRANDE OF WARINGTON.

Report of Mr. George Reasin on the Supply of Water from the District of Bagshot, 1850, p. 25. Reproduced in Prestwich's Water-bearing Strata, 1851, p. 224.

Sample taken 13th June, 1850.

	In grains per gallon.
Carbonate of lime	13·5
Sulphate of lime	1·2
Chloride of sodium	2·5
Silica	·4
Organic matters and water of combination	·4
Total	18

Hardness 17°.

Barnet

The Mineral Spring, on the Common, *see* p. 68.

In the Rev. W. M. TRINDER'S book, 1812, p. 66.

The solid contents, in grains per gallon, are as follows :—

Sulphate of magnesia	96
Muriate of magnesia	12
Carbonate of lime	16
Sulphate of lime	24
Extractive matter	7

It seems clearly a London Clay water.

Hatfield.

Hill End House. Spring. Water filtered.

Made and communicated by Dr. J. C. Thresh. April 1906.

Slightly dull. Yellow. No odour. Reaction neutral.
A fairly good water. Slight excess of vegetable matter.

	In parts per 100,000.
Chlorine	4·3
Equivalent to chlorides	7·2
Nitric nitrogen	·06
Equivalent to nitrates	·36
Nitrites	Nil.
Free ammonia	·004
Organic ammonia	·010
Oxygen absorbed in 3 hours at 37 C. ...	·120

Hardness: Permanent, 7·2°; Temporary, 5·7°; Total, 12·9°.

Rickmansworth.

Batchworth.

By Dr. T. Clark and Dr. John Smith. Reports . . . London (Watford) Spring Water Co. 1852, p. 50. Reprinted in *Roy. Comm. Water Supply* Minutes of Evidence, 1869, p. 411.

Analysis of the evaporated residuum of Batchworth Spring Water.

	In grains per gallon.	
	Original.	Softened.
Carbonate of lime	17·6	1·65
Nitrate of lime...	·08	·41
Nitrate of magnesia	1·42	1·05
Nitrate of soda	—	·09
Sulphate of soda	·5	·5
Chlorides of sodium and of potassium ...	1·3	1·3
Phosphorus	·28	·28
Silica	·82	·57
Volatile matter (including some nitric acid)...	1·	1·15
Residue on evaporation	23·	7·
Hardness, due to carbonate of lime ...	17·6°	1·65°
Hardness, due to nitrate of lime	·05°	·25°
Hardness, due to nitrate of magnesia ...	·95°	·7°
Total hardness	18·6°	2·6°
Subtract latent hardness (magnesium-salts)..	·95°	—
Sensible hardness [lime-salts]	17·65°	2·6°

Ware and Great Amwell.

In Ranger's Report to the General Board of Health on the supply of water to these places, 1849, p. 15, [Lord] Playfair gives the hardness of the water of eight springs as varying from 11° to 38°. The localities are doubtful.

ANALYSES OF WELL-WATERS. BUCKINGHAMSHIRE.

W. W. Fisher has sent the following general note. The waters from the Oolites (limestones) are generally rather hard, and when those beds are beneath surface-clay, whether Drift or other deposits, the waters contain considerable quantities of mineral and saline matters, and are sometimes alkaline. In the covered beds the nitrates are in small quantity; but free ammonia is often present.

Amersham.

Waterworks well 150 ft. deep, *see* p. 121.

A.—W. W. Fisher, *Analyst*, August, 1901.

B.—From Local Government Board.

	In grains per gallon.	
	A	B
Total solids	19·88	20·16
Chlorine in chlorides	·9	·9
Nitrogen in nitrates	·091	·091
Ammonia	·003	·003
Albuminoid ammonia	·001	·003
Oxygen absorbed in 3 hours	·002	·003

Another analysis by F. F. Shelley, Apothecaries Hall, gives the total hardness as 18·2°, after boiling 3°, temporary 15·2°.

Two later analyses. Made (13th November, 1901 and 22nd June, 1908) and communicated by W. T. Burgess.

	Parts per 100,000.		
	1901.		1908.
Total solid residue	30·4	...	30·3
Organic carbon	—	...	·018
Organic nitrogen	—	...	·003
Ammonia, free	0	...	0
,, albuminoid	·015	...	·0005
Nitrogen as nitrates	·160	...	·121
,, nitrites	0	...	0
Total combined nitrogen	—	...	·124
Oxygen consumed in 4 hours at 26·7° C. ...	·004	...	·008
Chlorine	1·	...	1·
Hardness, total by soap-test	25·1	...	25·1
,, temporary by soap-test	22·2	...	22·6
,, permanent	2·9	...	2·5

Clear (both).

Another analysis, from University College, London, communicated by Dr. J. S. New, M.O.H., of water from "Deep Mill" Pumping Station.

Physical character good. Reaction alkaline.

	In parts per 100,000.
Nitrogen as NO_3	·022
Chlorine	1·1
Phosphoric Acid	trace
Sulphuric acid	trace
Ammonia, free	·039
Ammonia, organic	·002
Oxygen absorbed at 80° F. in 2 hours	nil.

Hardness: Temporary, 8; Permanent, 10: Total, 18.

Dr. J. S. New, M.O.H., has sent me the following note on the Amersham district (1915). "The water percolating the upper gravels is often very chalybeate. A company once bottled this water, and the site of the works is called 'Minerals' to this day. In this type of water much of the watercress is grown, and for this reason they have found a peculiar type of plant which flourishes in it, which makes a large leaf, with a sort of bronzing in the colour. The peasantry impound rain-water in underground tanks, and strongly object to drinking 'company's water,' which is always hard."

Ashendon.

Ordnance Map 237, new ser. (Bucks. 27, SE.). Geologic Map 45, SE.

Watbridge. A farm in the valley, east of the village.

Well 16 ft. deep. Water from Corallian Oolite below Kimmeridge Clay.

W. W. Fisher, *Analyst*, 1904, vol. xxix, no. 335, p. 33.

	In grains per gallon.
Total solids	100·
Chlorine in chlorides	6·6
Nitrogen in nitrates	·812
Saline ammonia	·004
Albuminoid ammonia	·021
Oxygen absorbed in 3 hours	·097

Hard, Sulphate of lime.

The site is shown as Kimmeridge Clay on the Geologic Map 45, SE.

Beachampton.

Ordnance Map 219, new ser. (Bucks. 14, NW.). Geologic Map 46, NW.

1. Potash Farm, south-south-east of the village.

From a boring through 70 ft. of clay (Drift) into Oolite, from which the water comes.

Made (November, 1904) and communicated by W. W. Fisher.

	In grains per gallon.
Total solid residue, dried at 180° C.	150·9
The principal constituents are—	
Sodium chloride	27·52
Sodium sulphate	92·32
Sodium carbonate	10·6
Magnesium carbonate	11·71
Calcium carbonate	8·86
Total	151·01

The following added, from Local Government Board.

Chlorine	16·7
Ammonia	·133
Albuminoid ammonia	·004
Nitrogen as nitrates	·02
Oxygen absorbed	·058

This looks like a water from Drift rather than from Cornbrash, and so does the following.

2. From a new well 14 ft. deep, for cottages. Soil 4 ft., clay 8, to marly rock. Water, stands at 10 ft.

Made and communicated by W. W. Fisher.

Water from Oolite.

	In grains per gallon.
Total solids	68·
Chlorine	2·5
Ammonia	·01
Albuminoid ammonia	·008
Nitrogen as nitrates	·028
Oxygen absorbed	·047

Beaconsfield.

Well 270 ft. deep.

W. W. Fisher, *Analyst*, August, 1901,

	In grains per gallon.
Total solids	22·4
Chlorine in chlorides	1·
Nitrogen in nitrates	·21
Ammonia	·001
Albuminoid ammonia	·001
Oxygen absorbed in 3 hours	0

Bierton.

Ordnance Map 238, new ser. (Bucks. 28, SE.). Geologic Map 46, SW.

Well in Portland Beds, 12 ft. deep. Water hard.

W. W. Fisher, *Analyst*, July, 1902.

	In grains per gallon.
Total solids	38·
Chlorine in chlorides	1·8
Nitrogen in nitrates	·532
Saline ammonia	0
Albuminoid ammonia	·006
Oxygen absorbed in 3 hours	·03

Brickhill, Great.

Well of the Bletchley Urban District Council, *see* p. 123.

Information from the Local Government Board.

Water of good quality.

Free ammonia	·018 parts per million.
Albuminoid ammonia	·027 „ „
Chlorine	1·6 grains per gallon.

Hardness: Total, 6·1; Permanent, 6·1.

Total soluble solids, 12.

Brill.

Coldharbour Farm, Rids Hill, north-east of village.

Well 43 ft. deep. Water from Kimmeridge Clay, with vein of sand.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, pp. 33, 34.

	In grains per gallon.
Total solids	292·
Chlorine	17·
Sulphuric acid, SO_3	126·60
Carbon dioxide, CO_2	25·41
Lime, CaO	67·2
Magnesia, MgO	34·88
Soda	19.7
Silica, SiO_2 and Fe_2O_3	5·6
Probably combined as—	
Sodium chloride	28·01
Sodium sulphate	11·08
Magnesium sulphate	104·64
Magnesium carbonate	86·16
Calcium sulphate	56·64
Silica, &c.	5·6
	292·13
Nitrogen in nitrates	·028
Saline ammonia	·294
Albuminoid ammonia	·2
Oxygen absorbed in 3 hours	·26

The amount of magnesium sulphate is remarkable.

Buckingham.

1–3. Analyses of water from three wells.

Made and communicated by Dr. J. C. Thresh. November, 1897.

1. Kincher's Well. 2. Rectory Pump. 3. Public Well.

Buckingham, cont.

	In parts per 100,000.		
	1	2	3
Chlorine	6·9	3·6	2·4
Equivalent to chlorides ...	11·5	6·	3·5
Nitric Nitrogen	·71	1·	·43
Equivalent to nitrates ...	4·25	6·	2·55
Nitrites	very minute trace	nil	nil
Hardness	24·3	24·3	24·3
Free ammonia	—	—	·000
Organic ammonia	—	—	·012

3. Has a slight excess of organic matter.

4. Gawcott. Shallow wells for town-supply, *see* p. 124.

By W. W. Fisher.

A. From the Local Government Board, from the mains. Very slightly turbid No odour. Pale yellowish, in two-foot tube.

B.—From W. W. Fisher, from well No. 1, 14 ft. deep, near roadside.

	In grains per gallon.	
	A	B
Total dissolved solid matter	30·52	59·
Chlorine in chlorides	1·5	1·9
Ammonia, free and saline	·001	·001
Ammonia, albuminoid	·005	·004
Nitrogen in nitrates	·0476	·05
Nitrogen in nitrites	0	—
Oxygen required to oxidise organic matter, in 3 hours	·003	·005

The sample contains a moderate amount of dissolved mineral matter. The chlorides and nitrates are normal in quantity. The proportion of organic matter is very small. The water is an unpolluted supply suitable for drinking and domestic use.

For the public supply *see also* **Maid's Moreton.**

5. Well in the Chewar (? site).

By J. S. Sumner. From the Local Government Board.

No colour in 6-inch column. No turbidity. Clear and bright. Odour, extremely faint. Reaction, very slightly acid. Residue left on evaporation, heavy but of good quality. Does not char on ignition, showing absence of excess organic matter. Free ammonia, none. Traces of magnesia. Chlorine, between 4 and 6 grains to gallon. Equivalent of common salt, about 9 grains. Nitrites absent. Nitrates, less than one-tenth grain per gallon. Hardness about 7°, temporary. Slight traces of iron. No lead, zinc, or copper. Oxygen absorbed in 30 minutes at 212° F. 10 grains a gallon.

The water is pure, free from excess of organic matter and adapted to all domestic purposes.

Buckingham Rural District.

Public Supplies. Ann. Repts., M.O.H. (Dr. P. L. Benson); *a*, 1912; *b*, 1913; *c*, 1914.

Source and character of sample.	Grains per gallon.				Parts per million.		
	Chlorine.	Equivalent of Common Salt.	Nitrogen as Nitrates.	Total Hardness.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes at 212° F.
a Site of Infectious Hospital. Yellowish, slightly turbid	1·	1·65	·4	25·	·04	·05	·8
c Akeley, Pump	7·2	11·9	·3	27·	·06	·07	·9
Akeley, Tap. Faintly yellow. No turbidity ...	5·9	9·8	·5	40·	·03	·06	1·8
a Barton Hailstone. Colourless, no turbidity ...	2·	3·3	·25	26·	·03	·05	·25
c Charndon. Clear, colourless	3·6	6·1	·2	30·	·03	·05	1·4
a Chetwode, Fountain. Colourless, no turbidity	·6	1·	·02	28·	·01	·04	·7
c Edgcott. Clear, colourless	2·5	4·	·3	25·	·03	·07	·7
a Lillingston Lovell. Colourless, no turbidity ...	2·5	4·	·1	25·	·03	·07	·7
a Maid's Moreton, Duck Lake. Pale greenish, no turbidity	2·4	3·9	·02	26·	·03	·06	1·1
b Maid's Moreton Pump, Lower End. Greenish, clear	2·4	3·9	·02	26·	·03	·06	·7
c Marsh Gibbon Pump near Post Office. Yellowish, slight turbidity	12·5	20·6	·1	3·9	·16	·15	2·4
c Marsh Gibbon Pump near Public Hall. Yellowish, slight turbidity	8·	13·5	none	8·	·23	·1	1·8
b Pounden. Pale greenish, clear	1·	1·6	·2	38·	·03	·05	1·2

Buckingham Rural District—*continued.*

Source and character of sample.	Grains per gallon,				Parts per million.		
	Chlorine.	Equivalent of Common Salt.	Nitrogen as Nitrates.	Total Hardness.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed in 15 minutes at 212° F.
b Preston Bissett. Pale greenish, no turbidity	1·6	2·6	·04	28·	none	·06	1·1
a Shalstone, Fountain. Pale bluish, no turbidity	1·2	2·	·21	28·	·013	·04	·2
a Shalstone, Tap. Colourless, no turbidity ...	·6	1·	·075	28·	·013	·05	·7
c Steeple Claydon Public Pump. Pale greenish, no turbidity	6·5	14·7	1·2	41·	·04	·11	1·2
c Steeple Claydon Public Supply. Pale greenish, no turbidity	1·	1·6	·1	14·	none	·05	·4
b Thornborough, Pump No. 1. Pale greenish, no turbidity	2·7	4·5	·1	36·	·01	·05	1·6
c Thornborough Pump No. 2. Pale greenish, no turbidity	1·8	2·9	·3	31·	none	·04	1·4
a Tingewick, Jubilee Pump. Clear, bluish tinge	1·9	3·1	·1	25·	·02	·05	·138
b Tingewick Pump, Chapel Lane	2·4	3·9	·3	23·	·02	·05	·5
a Tingewick, Westwell Pump. Pale greenish, no turbidity	6·5	10·7	1·43	35·	·02	·06	·552
b Turweston. Faint bluish tint, no turbidity ...	·8	1·3	·1	25·	none	·03	none
b Twyford. Pale greenish, clear, no turbidity ...	·8	1·3	·08	28·	·03	·08	·4
b Westbury. Clear, colourless	·9	1·4	·4	26·	·02	·05	·8

Buckland.

Chiltern Hills Water Works. *See* p. 124.

By — CAMPBELL, March, 1865.

Royal Commission on Water Supply, Minutes of Evidence, 1869, pp. 409, 410. Also *Proc. Inst. C.E.*, 1877, vol. xlviii, p. 159, and *Journ. Soc. Arts*, 1877, vol. xxv, p. 657. Also, less fully, in *R. Comm. Water Supply, Report*, 1869, p. 410.

	In grains per gallon.
Total solid contents (mineral matter 19·44, volatilized matter ·72)	20·16
The mineral matter composed as follows:—	
Sulphate of sodium	2·
Chloride of sodium	1·17
Chloride of potassium	1·2
Carbonate of lime	12·96
Sulphate of lime	Trace.
Nitrate of lime	Trace.
Magnesia (probably as silicate)	·37
Silica	1·44
Oxide of iron	·3
Nitric acid	Trace.

Hardness: 13·25°.

After softening, by Clark's process, the solid contents were 8·24 (mineral matter 7·64, volatilized matter ·6), and the hardness was 2·2 .

Another analysis in Sixth Report Rivers Pollution Commission, 1874, p. 101. Temperature of the water 9·2° Centigrade. November, 1868.

	In parts per 100,000.
Total solid impurity	28·6
Organic carbon	·036
Organic nitrogen	·01
Ammonia	·001
Nitrogen as nitrates and nitrites	·094
Total combined nitrogen	·105
Chlorine	1·39

Hardness: Temporary, 23· ; Permanent, 3·3 ; Total, 26·3.

Burnham.

Burnham, Dorney and Hitcham Waterworks. *See* p. 125.

From the Local Government Board.

By W. W. FISHER.

A.—15th March, 1911.

B.—Sample received 18th January, 1913.

A.—Bright and clear; no odour. *B.*—Colour in two-foot tube pale yellowish green.

	In grains per gallon.	
	A	B
Total dissolved solid matters	27·16	27·44
Chlorine in chlorides	1·6	1·3
Ammonia, free and saline	·003	·001
Ammonia, albuminoid	·005	·001
Nitrogen in nitrates	·516	·63
Nitrogen in nitrites	0	0
Oxygen required to oxidize organic matter, in 3 hours	·003	·009
Hardness, total	18·7°	20·7°
,, temporary	13·5°	12·5°
,, permanent	5·2°	8·2°

The quantities of dissolved mineral solids, of chlorides and of nitrates are normal for a Chalk-water. The proportion of organic matter is very small. The water is of excellent quality.

Charndon.

Three analyses, made and communicated by Dr. J. C. Thresh.

A.—"Top" pump in village. August, 1897.
B.—Well in village. August, 1897.
C.—Trial-bore near village. April, 1898.

	A	B	C
Chlorine	6·9	5·	1·6
Equivalent to chlorides	11·5	8·3	2·7
Nitric nitrogen	·00	·07	nil.
Equivalent to nitrates	0	·42	nil.
Nitrites	nil	nil	nil
Hardness — Permanent	—	2°	4·3°
Hardness — Temporary	38°	40°	18·6°
Hardness — Total	38·6°	42°	22·9°
Lead, Copper, Zinc, Iron	Trace of zinc.	Trace of iron.	nil
Free Ammonia	·012	·088	·014
Organic Ammonia	·004	·012	·006
Oxygen absorbed in 3 hours, at 37° C.	·036	·044	·064

A.—Very hard, otherwise good.
B.—Excessively hard. Contains too much organic matter.
C.—Somewhat hard, but a very good water.
See also table, p. 281.

Chearsley.

Ordnance Map 237, new ser. (Bucks. 32, NE.). Geologic Map 45, SE.

Made and communicated by W. W. Fisher.

Good water, from the Portland Beds.

	In grains per gallon.
Total solids	28·28
Chlorine in chlorides	1·1
Ammonia, free	·002
Ammonia, albuminoid	·004
Nitrogen as nitrates	·343
Oxygen absorbed in 3 hours	·008

Cheddington.

Public supply, *see* p. 128.
Well 213 ft. deep, through Gault into Lower Greensand. Water-level 113 ft. down.

W. W. Fisher, *Analyst*, July, 1902.

	In grains per gallon.
Chlorine	1·9
Sulphuric acid, SO_3	1·91
Carbon dioxide, CO_2	8·08
Soda, Na_2O	[4·16]
Magnesia, MgO	1·54
Lime, CaO	6·3
Silica, SiO_2	2·21
Fe_2O_3	·21
Probably combined as—	
Sodium chloride	3·13
Sodium sulphate	3·38
Sodium carbonate	2·48
Magnesium carbonate	3·22
Calcium carbonate	11·25
Total solids	26·6
Nitrogen in nitrates	·014
Saline ammonia	·032
Albuminoid ammonia	·003
Oxygen absorbed in 3 hours	·024
Hardness	9·7

Cheddington, cont.

Later. From the boring for the Wing Rural District Council.

Made and communicated by Dr. J. C. Thresh.

Sample taken after 14 days' trial-pumping; September, 1906.

In parts per 100,000.

		Probably combined as :—	
Ca	7·45	Calcium carbonate ...	18·65
Mg	·45	Magnesium carbonate ...	1·6
Na	4.	Sodium carbonate ...	3·25
Co_3	14·2	Sodium sulphate ...	2·65
SO_4	1·8	Sodium chloride ...	4·3
Cl	2·6	Sodium nitrate ...	·2
NO_3	·15	Etc. ...	·85
Total solid constituents dried at 180° C. ...			31·5

Hardness, total 21°

Free ammonia	·048
Organic ammonia	·001
Oxygen absorbed in 3 hours at 37 C. ...	·009
Nitrites	Nil.

Colour dull. A little fine sand and clay.

Chesham.

Waterworks, *see* p. 129.

1. From the Local Government Board, made by the Clinical Research Association.

Of a sample received in May, 1908, it is said that it is a water of a very high degree of organic purity. With the exception that chlorides are a trifle higher, it is almost identical with the last sample received. The following are later :—

A.—Received 6th March, 1911.

B.—Received 6th November, 1912.

In parts per 100,000

	A	B
Total solids dried at 120° C.	28·2	28·5
Combined chlorine	·86	1·1
Expressed as NaCl.	1·41	1·81
Nitrogen as nitrates (nitric nitrogen)	·24	(·3)
Nitrites (nitrous nitrogen)	nil	nil
Saline ammonia (ammoniacal nitrogen)	nil	nil
Albuminoid ammonia	·0009	·001
Oxygen absorbed in 4 hours at 27° C.	·01	·007
Lead or copper	nil	nil
Temporary hardness	15·8°	22·2°
Permanent hardness	1·1°	nil
Total	16·9°	22·2°

These results show that the water is of satisfactory organic purity.

An analysis given in the Water Works Directory, 1911, p. 86, is of the same character.

2. Made and communicated by W. W. Fisher.

In grains per gallon.

Total solids	19·6
Chlorine as chlorides	·8
Ammonia, free	0
Ammonia, albuminoid	·001
Nitrogen as nitrates	·203
Oxygen absorbed in 3 hours	0

Chilton.

Chilton Grove Farm. *See* p. 95.

By A. Dupre in Report of the Medical Officer of the Privy Council New. ser. No. ii, pp. 123, 124, 128. 1874.

In grains per gallon.

A.—Farm Well. Sample taken 30th Aug., 1873.
B.—Dairy Well. Sample received 14th Aug., 1873.
C.—Farm Well ? Sample collected 29th Aug., 1873.

	A.	B.	C.
Appearance	turbid	turbid	very turbid
Colour	yellowish-brown	yellowish-brown	brownish-yellow
Smell	Musty	Inodorous	Slightly putrid
Deposit	slight	slight	much brown flocculent
Nitrous acid	very minute trace	none	none
Phosphoric acid	very strong trace	very strong trace	much
Hardness before boiling	22°	36°	22°
Hardness after boiling	4·6°	17°	5·5°
Oxygen absorbed from permanganate	·1008	·112	·314
Total dry residue	114·38	121·66	46·48
Consisting of { volatile matters	10·36	11·48	6·38
Consisting of { fixed salts	104·02	110·18	40·1
Chlorine	5·46	7·315	5·81
Nitric acid (N_2O_5)	·68	·37	·11
Nitrogen in ammonia	·073	·0147	·045
Organic nitrogen	0·25	·0273	·063

All show strong signs of contamination.

Claydon, East.

Ordnance Map 219, new ser. (Bucks. 18, SE.). Geologic Map 45, SE.

Public well ?

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 32.

In grains per gallon.

Total solids	238·
Chlorine in chlorides	5·9
Nitrogen in nitrates	·021
Saline ammonia	·015
Albuminoid ammonia	·01
Oxygen absorbed in 3 hours	·03

? From Oxford Clay or from Drift.

For analyses of waters from other East Claydon wells, *see* p. 308.

Datchet.

Slough Waterworks. *See* p. 131.

1. Two analyses made and communicated by Dr. J. C. Thresh. 1912.

A.—A sixteenth of a mile from the Thames.
B.—An eighth of a mile from the Thames.

Water could not be kept from the three borings, but samples were got from the wells nearest and furthest from the river.

	A	B	Probably combined as:—	In parts per 100,000 A	B
Ca	6·5	5·9	Calcium carbonate ...	16·25	14·7
Mg	1·05	·9	Magnesium carbonate	3·6	3·1
Na	6·65	7·4	Sodium carbonate ...	3·7	5·65
CO_3	14·4	14·2	Sodium sulphate ...	7·55	7·65
SO_4	5·1	5·15	Sodium chloride ...	5·75	5·6
Cl	3·5	3·4	Sodium nitrate ...	1·25	1·25
NO_3	·9	·9	Silica, etc.	1·3	1·75
			Total solid constituents dried at 180° C.	39·4	39·7

Datchet, cont.

A.—Hardness: temporary 15°, permanent 7°, total 22°

B.— „ „ 12°, „ 6°, „ 18°

Free ammonia	·023	·0104
Organic ammonia	·005	·005
Oxygen absorbed in 3 hours at 37° C. ...	·023	·033
Nitrites	nil	—

Both clear and bright, pale blue, no odour. Reaction alkaline?

2. Made and communicated by W. W. Fisher.

In grains per gallons.

Total solids	26·88
Chlorine as chlorides	2·05
Ammonia, free	·004
Ammonia, albuminoid	·005
Nitrogen as nitrates	·05
Oxygen absorbed in 3 hours	·003

3. From the Local Government Board.

By Dr. S. Rideal. Sample taken 3rd February, 1912.

	In parts per 100,000
Total solids	35·8
Chlorine	2·7
Free ammonia	·0002
Albuminoid ammonia	·0025
Nitrates (as nitrogen)	·092
Nitrites	nil
Oxygen consumed	·086
Total hardness	21·7 (15·17° Clark)
Permanent hardness	5·5 (3·8° Clark)

Clear, colourless, inodorous, no sediment. This water is of good chemical quality.

Ellesborough.

1. Boring 18 ft. deep, at School (for Bucks. Education Comm.)

Made (1909) and communicated by W. W. Fisher.

	In grains per gallon.
Total solids	32·
Chlorine in chlorides	·75
Free ammonia	·004
Albuminoid ammonia	·01
Nitrogen in nitrates	·252
Oxygen absorbed in 3 hours	·037

2. Chequers Court. *See* p. 133.

Made and communicated by Dr. J. C. Thresh. 1909.

		Probably combined as:—	In parts per 100,000
Ca	9·3		
Mg	1·3	Calcium carbonate	23·2
Na	·95	Magnesium carbonate	2·
CO_3	15·3	Magnesium sulphate	3·5
SO_4	2·8	Sodium chloride	2·3
Cl	1·4	Sodium nitrate	·2
NO_3	·15 (or ·16)	Silica, etc.	1·9
		Total solid constituents dried at 180° C.	33·1

Hardness: Temporary, 18°; Permanent, 6°; Total, 24°.

Free ammonia	·014
Organic ammonia	·0018
Nitrites	nil

Emberton.

Geologic Map 203, new ser.

Trial boring. *See* p. 133.

Made (February, 1909) and communicated by W. W. Fisher.

	In grains per gallon.
Sodium chloride	42·7
Magnesium chloride	28·88
Magnesium sulphate	108·
Calcium sulphate...	110·4
Calcium carbonate	28·
Total	317·98

"This water contains a remarkable amount of magnesium-salts, and is unsuited for domestic purposes in consequence."

Farnham Royal.

Ordnance Map 255, new ser. (Bucks. 53, SW.). Geologic Map 7.

Well 60 ft. deep.

W. W. Fisher, *Analyst.* August, 1901.

	In grains per gallon.
Total solids	19·
Chlorine in chlorides	1·8
Nitrogen in nitrates	·231
Ammonia	·001
Albuminoid ammonia	·003
Oxygen absorbed in 3 hours	·023

Fawley.

Well 330 ft. deep.

W. W. Fisher, *Analyst.* August, 1901.

	In grains per gallon.
Total solids	38·
Chlorine in chlorides	2·1
Nitrogen in nitrates	·84
Ammonia	·004
Albuminoid ammonia	·003
Oxygen absorbed in 3 hours	0
Hardness	26·2

Fenny Stratford.

Bletchley Railway Station, *see* p. 134.

By A. Timmins.

A.—From 390 ft. down.

B.—From 410.

	In grains per gallon.	
	A	B
Solid matter	340·	392·
Combined chlorine	75·	91·4
Sulphuric anhydride	108·08	123·24
Calcium oxide	20·02	9·98
Magnesium oxide	4·89	4·37
Residue principally soda	—	—
Equivalent to—		
Sodium-chloride	123	150
Sodium-sulphate	162	185

Grendon Underwood.

Ordnance Map 219, new ser. (Bucks. 22, SE.). Geologic Map 45, SE.

Well 20 ft. deep? Water from Oolite below Oxford Clay. Soft, alkaline.

W. W. Fisher, *Analyst.* 1904, vol. xxix, No. 335, p. 31.

	In grains per gallon.
Total solids	360·
Chlorine in chlorides	118·3
Nitrogen in nitrates	·021
Saline ammonia	·042
Albuminoid ammonia	·005
Oxygen absorbed in 3 hours	·026

Hanslope.

1. Well, said to be 90 ft. through clay.

Made (April, 1907) and communicated by W. W. Fisher, who thinks that this was from an earlier boring than the following, which was made because the water of this was unsuitable.

	In grains per gallon.
Total solids, dried at 180° C.	242·
The chief constituents are—	
Sodium chloride	34·51
Magnesium chloride	32·01
Magnesium sulphate	37·56
Calcium sulphate	124·
Calcium carbonate	23·8
Total	251·88

Some loss on drying, from decomposition of the magnesium chloride. The amount of magnesium-salts is noteworthy.

Another analysis gives the following figures:—

Total solids	250·
Chlorine	38·5
Ammonia	·004
Albuminoid ammonia	·006
Nitrogen as nitrates	·084
Oxygen absorbed	·054

2. New Well of the Newport Pagnell Rural District Council. 107 ft. deep, *see* p.137.

By W. W. Fisher. February, 1909.

	In grains per gallon.
Total dissolved solid matter, dried at 180° C.	60·
Chlorine in chlorides	4·
Ammonia, free and saline	·004
„ albuminoid	·004
Nitrogen in nitrates	·042
„ nitrites	0
Oxygen required to oxidize organic matter (3 hours)	·025

Sample slightly turbid. Odour none, or very slight. Colour, in two-ft. tube, pale yellowish.

The total dissolved mineral matter is somewhat above the average, and the water is correspondingly hard. The chlorides are moderate in quantity, while the proportions of organic matter and of nitrates are very small. The water is an unpolluted natural supply of satisfactory quality, and suitable for drinking and domestic purposes.

The hardness may lessen after the water has been in use for some time.

Another analysis, in March, 1909, showed the total solids and the chlorides in rather larger amount. The temporary hardness, due to carbonate of lime, which is removed on boiling, was about normal; but the permanent hardness, chiefly due to sulphate of lime (with a little magnesia) was rather over the normal.

Permanent hardness 26·2. Temporary 18·5. Total 44·7.

Hanslope, cont.

3. From the main. December, 1915.

Made and communicated by Dr. J. C. Thresh.

Slight flocculent precipitate of oxide of iron and organic matter. Faint green. No odour. Reaction neutral.

In parts per 100,000.

		Probable combinations:—	
Ca	19·6	Calcium carbonate	34·
Mg	2·	Calcium sulphate	20·4
Na	6·	Magnesium sulphate	9·9
Fe	trace	Sodium sulphate	7·5
CO_3	20·4	Sodium chloride	9·6
SO_4	27·3	Sodium nitrate	1·1
Cl	5·8	Silica, oxide of iron, etc.	2·5
NO_3	·8		

Total solid constituents dried at 180° C.... ...	85·
Free ammonia	·002
Organic ammonia	·0014
Oxygen absorbed in 3 hours at 37° C.	·02
Nitrites	nil

Hardness: Temporary 31°. Permanent 25°. Total 56°.

Haversham.

Geologic Map 203, new ser. (Bucks. 9, NE.).

Well 30 ft. deep, on Wolverton road.

Analysis made and communicated by W. W. Fisher.

In grains per gallon.

Total solids	41·
Chlorine	1·7
Ammonia	·001
Albuminoid ammonia	·005
Nitrogen as nitrates	·14
Oxygen absorbed	·02

Water presumably from Great Oolite.

Horwood, Little.

1. Horwood House. *See* p. 138.

Made by Harland and Brown. Communicated by Mr. Ditmer Blow.

(1) December, 1909. (2) Well in yard, January, 1910, (3) Pump in park, January, 1910. (4) From pump delivering into 5,000 gallon tank.

	(1)	(2)	(3)	(4)
Colour in 2-ft. tube	pale blue.	pale blue; clear.	pale blue; clear.	pale blue.
Suspended matter	traces	nil	nil	traces
Smell	nil	nil	nil	nil
Hardness before boiling (total)... ...	12°	30°	26°	15°
,, after boiling (permanent) ...	12°	—	—	15°
	Grains per gallon.			
Total dissolved solids	20·3	59·5	44·1	18·5
Chlorine	·99	7·85	3·87	·89
(equal to chloride of sodium).	(1·64)	(12·94)	(6·39)	(1·47)
Lead, copper, iron	nil	nil	nil	nil
Nitrogen as saline ammonia	·0022	·0033	·0022	·0011
,, albuminoid Ammonia ...	·0034	·0044	·0045	·0017
,, nitrites	nil	nil	nil	nil
,, nitrates	·224	2·24	·616	·1389
Oxygen absorbed by organic matter at 27° in 15 minutes	·0028	·0196	·0112	·0028
Oxygen absorbed by organic matter at 27° in 4 hours	·0084	·0532	·0308	·014

Horwood, cont.

Remarks:—(1) Free from animal pollution. Hardness not excessive. Slight turbidity probably due to recent construction and likely to disappear with further pumping. Good for drinking and general domestic purposes. (2) Very hard and contains a large amount of dissolved solids. The nitrates also are in excess. If from a shallow well it is probably contaminated by surface drainage the organic matter of which has been oxidised in passage through surrounding soil. Not satisfactory for drinking and domestic purposes. (3) No evidence of animal pollution. Satisfactory for drinking, but rather hard for general domestic use. (4) Practically identical with (1) and free from animal pollution. Perfectly satisfactory in every way for drinking and domestic purposes.

The mineral salts of (4) were as follows:—

	Grains per gallon.
Calcium carbonate	14·41
Magnesium carbonate	·25
Calcium sulphate	·82
,, nitrate	·81
Sodium chloride	1·47
	17·76
Organic matter, etc.	·74
	18·5

The mineral analysis shows it to possess the characters of ordinary Chalk-water.

By Messrs. Harland and Brown.

A.—Sample from the bottom of the 8-inch tube, after sealing the 6-inch tube below and pumping for a considerable time (drawn on 16th March) 21st March, 1911.

B.—Sample of "water developed" at a depth of 40 ft. (drawn on 30th March) 4th April, 1911.

	A	B
Colour in tube 2-ft. long	turbid	pale blue, clear.
Suspended matter	heavy	trace
Smell	none	none
Hardness	6·5°	30°
	In grains per gallon.	
Total dissolved solids	20·58	38·1
Chlorine	·89	1·39
Equal chloride of sodium	1·47	—
Lead, copper, iron	nil	nil
Nitrogen as saline ammonia	·0162	·0011
Nitrogen as albuminoid ammonia	·0107	·006
Nitrogen as nitrites	nil	nil
Nitrogen as nitrates	·173	·455
Oxygen absorbed by organic matter in 15 minutes at 27° C.	·3743	·0028
Oxygen absorbed by organic matter in 4 hours	·6635	·0134

A.—Turbid owing to mineral matter in suspension. The figures for nitrogen, as saline and albuminoid ammonia and for oxygen absorbed are high, particularly the last, and show that there is organic pollution. Another sample to be taken after a whole day's pumping.

B.—As compared with the above great improvement is shown. There is no evidence of animal pollution, and the analytical data show that the water is satisfactory for drinking. Softening is advisable, for domestic use.

The mineral salts (in B) are probably combined as follows:—

	In grains per gallon.
Calcium carbonate	22·96
Calcium sulphate	6·6
Calcium nitrate	·32
Magnesium nitrate	2·14
Magnesium chloride	·92
Sodium chloride	1·15
Combined water, etc.	4·01
Total	38·1

Horwood, cont.

2. Public Supply. (? source.)

Made and communicated by Dr. J. C. Thresh. February, 1916.

Trace of oxide of iron, with vegetable growth. Faint green. No odour. Reaction neutral.

In parts per 100,000.

		Probable combinations :—	
Ca	9·6	Calcium carbonate	20·5
Mg	trace.	Calcium sulphate	4·25
Fe	trace.	Sodium chloride	3·
CO_3	12·3	Sodium nitrate	2·3
SO_4	3·	Silica, iron-oxide, etc. ...	·95
Cl	1·8	... ...	—
NO_3	1·7	Total solid constituents dried at 180° C.	31·
		Free ammonia	·004
		Organic ammonia	·003
		Oxygen absorbed in 3 hours at 37° C. ...	·025
		Nitrites	nil.

Hardness: Temporary, 19·5°; Permanent, 4.5°; Total, 24°.

Iver.

Iver Place. Well 240 ft. deep, 104 in Chalk.

Analysis made and communicated by W. W. Fisher.

In grains per gallon.

Total solids	20·16
Chlorine as chlorides	·9
Ammonia, free	·006
Ammonia, albuminoid	·001
Nitrogen as nitrates	·021
Oxygen absorbed in 3 hours	·008

Ivinghoe.

Brewery. *See* p. 140.

By W. Loftus.

In grains per gallon ?

	Old Well.	New Well.
Specific gravity	1000·39	1000·35
Inorganic matter	27·58	26·14
Organic and volatile	1·23	1·44
Total residue	28·81	27·58
Sulphate of lime	5·42	4·41
Carbonate of lime	11·1	11·5
,, of magnesia	1·32	1·26
Potash and soda	1·7	1·56
Hardness	17·	16·5
,, after boiling	4·3	3·5

Lane End.

Geologic Map 254. New ser.

1. Wycombe Court. Deep boring. *See* p. 140. Two shallow wells in gravel on the same estate.

Analysis made and communicated by W. W. Fisher.

In grains per gallon.

	(1)	(2)
Total solids...	21·28	21·
Chlorine as chlorides	1·	4·2
Ammonia, free	·001	·003
Ammonia, albuminoid	·003	·008
Nitrogen as nitrates	·147	·385
Oxygen absorbed in 3 hours ...	0	·05

1. Total hardness, 15·5°; Permanent, 3°.

Linford, Little.

Public Supply. *See* p. 141.

By W. W. Fisher. From the Local Government Board. July, 1912. New well. Slightly turbid. No odour. Colour in two-foot tube pale yellowish-green.

	In grains per gallon.
Total dissolved solid matter	48·
Chlorine in chlorides	1·4
Ammonia, free and saline	·01
„ albuminoid	·003
Nitrogen in nitrates	·014
„ nitrites	slight trace
Oxygen required to oxidize organic matter in 3 hours	·027

Hardness: Total, 30°; after boiling, 13°; temporary, 17°.

The quantity of the dissolved mineral constituents is rather over the average, and the water is somewhat hard. The chlorides and nitrates are normal and the proportion of organic matter is small. An unpolluted natural supply of satisfactory quality.

A later analysis from the Main. December, 1915.

Supplies 23 houses.

Made and communicated by Dr. J. C. Thresh.

Faintest opalescence. Green-yellow tint. No odour. Reaction neutral.

			In parts per 100,000.
		Probable combinations:—	
Ca	18·6	Calcium carbonate	34·
Mg	·9	Calcium sulphate	17·
Na	1·95	Magnesium sulphate	1·
Fe	trace	Magnesium chloride	2·7
CO_3	20·4	Sodium chloride	3·3
SO_4	12·8	Sodium nitrate	2·35
Cl	4·	Silica, etc.	2·65
NO_3	1·7		
		Total solid constituents dried at 180° C.	63·
		Free ammonia	·004
		Organic ammonia	·0063
		Oxygen absorbed in 3 hours at 37° C. ...	·06
		Nitrites	nil

Hardness: Temporary, 32°; Permanent, 18°; Total, 50°.

Linslade.

1. Trial-boring, for public supply of Linslade. *See* p. 142.

Made and communicated by Dr. J. C. Thresh. July, 1900.

The water was not pumped, but a sample was taken from the bore-hole by means of a shell. This bore-hole was abandoned.

"This water was very turbid, from the presence of very fine brown sand. Even after standing some hours a little sand remained suspended. There may therefore be, especially at first, some difficulty in obtaining a perfectly bright water from the bore."

"The saline constituents show that it is one of the Greensand waters which is not likely to give trouble from the presence of iron-salts. There is not a trace in the water and the sand contains but little."

"It is somewhat hard, but most of the hardness is removed by boiling. The magnesia salts are small in amount. The chlorides and nitrates are very low and show that there is no admixture with water derived from heavily manured land. The organic matter is small in quantity and will certainly be still less when a proper well is constructed and some quantity of water abstracted."

"I am of opinion that the water will be quite satisfactory for a public supply, assuming that there is no source of pollution within some little distance of the well."

Linslade, cont.

In parts per 100,000.

		Probable combinations (besides a little sedimentary matter)	
Ca	10·35	Calcium carbonate	23·4
Mg	·7	Calcium sulphate	3·4
Na	·55	Magnesium sulphate	3·
CO_3	14·05	Magnesium chloride	·4
SO_4	4·8	Sodium chloride	1·15
Cl	1·	Sodium nitrate	·4
NO_3	·3	Ferric oxide (causing turbidity) ...	·7
		Silica, etc.	1·55
		Total solid constituents, dried at 180° C.	34·

Free ammonia	·0064
Organic ammonia	·0074
Oxygen absorbed in 4 hours, at 27° C.	·05

No nitrates.

Hardness: Temporary, 16°; Permanent, 9°; Total, 25°.

2. Three analyses made after the works were established, *see* p. 142.

Made and communicated by Dr. J. C. Thresh.

A.—Sample from the service-main (aerated and filtered), May 29th, 1903.
B.—April, 1905.
C.—Aerated and filtered, 20th August, 1908.
A.—Clear and bright. Faint green tint. No odour. Reaction neutral.
B.—Slight turbidity. Faint green tint. No odour. Reaction neutral.
C.—A little red matter present.

In parts per 100,000.

	A	B	C	Probable combinations.	A	B	C
Ca	10·1	13·7	14	Calcium carbonate ...	18·8	26·3	27·9
Mg	·75	1·15	·55	Calcium sulphate ...	8·85	10·9	9·5
Na	3·85	·09	—	Magnesium sulphate ...	3·75	3·75	—
Fe	nil	trace	—	Magnesium chloride ...	—	1·5	1·9
CO_3	11·3	15·8	16·7	Sodium sulphate ...	8·5	—	·0
SO_4	15·	10·7	6·7	Sodium chloride ...	2·8	·0	·0
Cl	1·7	1·1	1·4	Sodium nitrate ...	—	·35	—
NO_3	·25	·25	·4	Magnesium nitrate ...	—	—	·45
				Nitrates	·3	—	—
				Silica, etc.	·5	1·5	2·85
				Total solid constituents, dried at 180° C. ...	43·5	44·3	42·6
				Hardness { Temporary	17°	24°	25°
				Hardness { Permanent	10°	15°	13°
				Hardness { Total	27°	39°	38°
				Free ammonia	·001	·000	·0004
				Organic ammonia	·004	·004	·0006
				Oxygen absorbed in 3 hours at 37° C.	·068	·05	·016
				Nitrates	mere trace	mere trace	nil

A.—The water was ferruginous and rapidly deposited oxide of iron.

3. Boring for the Wing Rural District Council, *see* p. 143.

By Dr. J. C. Thresh. 1906.

In parts per 100,000.

		Probably combined as—	
Ca	17·6	Calcium carbonate	38·15
Mg	3·	Calcium sulphate	4·6
Na	5·1	Magnesium sulphate	14·85
CO_3	22·9	Sodium sulphate	6·35
SO_4	19·4	Sodium chloride	7·6
Cl	4·6	Sodium nitrate	·15
NO_3	·1	Silica, etc.	·3
		Total solid constituents dried at 180° C. ...	72·

Linslade, cont.

Hardness: Temporary, 41°; Permanent, 19°; Total, 60°.

Free ammonia	·002
Organic ammonia	·016
Oxygen absorbed in 3 hours at 37° C.	·448
Nitrites	nil.

Long Crendon.

Made and communicated by W. W. Fisher.

Good water, rather hard, from Portland Beds.

	In grains per gallon.
Total solids	40·
Chlorine in chlorides	1·9
Free ammonia	·001
Albuminoid ammonia	·003
Nitrogen in nitrates	·469
Oxygen absorbed in 3 hours	·018

Maid's Moreton.

Buckingham Waterworks. 1901. *See* p. 144.

1. Well 301 ft. deep. Water from Great Oolite.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 30 (three).

A.—Beginning of pumping test (August, 1901).

B.—Seven days later.

C.—Seven days later, after continuous pumping. With three added since.

	In grains per gallon.					
	A	B	C	4th June, 1903.	14th Aug., 1907.	28th Oct., 1908.
Total solids	60·	68·7	30·	27·7	30·	32·2
Chlorine in chlorides	8·2	10·	2·	1·35	1·	1·4
Nitrogen in nitrates	·014	·014	·014	·52	·02	·02
Saline ammonia	·017	·016	·021	·008	·02	·029
Albuminoid ammonia	·001	·002	·002	·005	·004	·005
Oxygen absorbed in 3 hrs.	·016	·016	·015	·007	·007	·015

2. Made by W. W. Fisher, August, 1907.
(for part, *see* table, No. 1.)

No nitrates. Odour, none. Colour in two-foot tube, pale bluish.

The total quantity of dissolved mineral and saline constituents is moderate, and the water is moderately hard. The amounts of chlorides and of nitrates are normal, while the proportion of organic matter is very small. A trace of free ammonia is present in most deep well-waters of the district.

The water has the composition and characters of an unpolluted natural supply and is of good quality for drinking and domestic purposes.

The analysis of the dissolved solids is as follows.

Chlorine	1·
Sulphuric acid, SO	3·84
Carbonic acid, CO_2	9·39
Lime, CaO	9·38
Magnesia, MgO	1·31
Soda Na_2O, with traces of potash indirectly determined	4·66
Silica	·77

These constituents may be combined as follows:—

Maid's Moreton, cont.

With them, for contrast, is given a second column of figures, from an analysis of 10th August, 1901.

Sodium chloride	1·65	16·42
Sodium sulphate	6·82	24·35
Sodium carbonate	1·38	16·
Magnesium carbonate	2·75	trace
Calcium carbonate	16·75	10·08
Silica	·77	1·4 (including iron-oxide
Total	30·12	68·25
		Loss ·49
		68·74

The composition of this residue is typical of a water from the Oolites where they are covered by impervious clay, and the proportion of alkaline salts, especially sulphate and carbonate of soda, is relatively larger than in Oolitic waters from springs or permeable deposits.

It is interesting to notice the change in the composition of this supply since the boring was made, in 1901, and the gradual fall in the amounts of the more soluble constituents, such as alkaline salts.

In the future little change may be expected beyond a small diminution of the sodium sulphate.

Some of the changes that have taken place in this water, as pumping has gone on, are shown in the table at the head (1). The first water examined, in 1901, contained 18·7 grains of sodium-chloride and 9·6 of sodium-carbonate.

Mr. FISHER adds:—These waters for some time past seem to be fairly steady in composition, but I think they have a supplementary well, the water from which may be mixed at times with the deeper supply (March, 1916).

3. By W. W. FISHER. From the Local Government Board.

1. Received 30th August, 1912.
2. From another boring, received 29th August, 1912.

In both: Odour none. Colour in two-foot tube, whitish turbidity.

	In grains per gallon.	
	1	2
Total dissolved solid matter	38·92	35·
Chlorine in chlorides	1·3	1·3
Ammonia, free and saline	0	·024
Ammonia, albuminoid	·001	·001
Nitrogen in nitrates	·014	·014
Nitrogen in nitrites	0	0
Oxygen required to oxidize organic matter and iron, in 3 hours	·078	·019

The total dissolved solids, and the chlorides and nitrates are normal in amount. The proportion of organic matter is small. The water is an unpolluted supply, suitable for drinking and domestic purposes.

4. Taken from the reservoir of the Buckingham Waterworks.

Made and communicated by Dr. J. C. THRESH. February, 1916.

Faint opalescence and trace of iron-oxide. Greenish tint. No odour. Reaction neutral.

		In parts per 100,000.	
		Probable combinations:—	
Ca	12·3	Calcium carbonate	30·7
Mg	1·6	Magnesium sulphate ...	7·9
Na	5·9	Sodium sulphate	13·7
Fe	trace.	Sodium chloride	3·
CO_3	18·4	Sodium nitrate	1·2
SO_4	15·6	Silica, oxide of iron, etc. ...	1·
Cl	1·8		
NO_3	·9	Total solid constituents dried at 180° C.	57·5

Maid's Moretor, cont.

Free ammonia	·014
Organic ammonia	·002
Oxygen absorbed in 3 hours at 37° C. ...	·018
Nitrites	nil.

Hardness: Temporary, 27½°; Permanent, 9½°; Total, 37°.

For analyses of two other Maid's Moreton waters, *see* table, p. 281.

Marlow, Great.

Well 260 ft. deep. *See* p. 147.

W. W. Fisher, *Analyst*, August, 1901. (The figures in brackets are from an analysis in August, 1900, from the Local Government Board.)

	In grains per gallon.	
Total solids	23·2	(23·5)
Chlorine in chlorides	1·	
Nitrogen in nitrates	·259	(·252)
Nitrogen in nitrites	—	(0)
Ammonia	·001	
Albuminoid ammonia	·001	
Oxygen absorbed in 3 hours	0	(·008)

Marsh Gibbon.

Well 100 ft. deep? Water from Oolite below Oxford Clay. Overflowed. Peaty, alkaline, nearly sterile.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, pp. 31, 34.

	In grains per gallon.
Total solids	53·2
Chlorine	5·3
Sulphuric acid, SO_3	6·05
Carbon dioxide, CO_2	14·01
Lime, CaO	2·31
Magnesia, MgO	·73
Silica, etc.	?
Probably combined as:—	
Sodium chloride	8·73
Sodium sulphate	10·74
Sodium carbonate	27 44
Magnesium carbonate ...	1·53
Calcium carbonate	4·13
	52·57
Nitrogen in nitrates	·014
Saline ammonia	·02
Albuminoid ammonia ...	·005
Oxygen absorbed in 3 hours ...	·253

Mr. Fisher says that wells here yield brown waters, containing peaty solids, dissolved by sodium-carbonate, *see* table, p. 281.

Marston, North.

1. For the Parish Council, *see* p. 148.

Made (July, 1895) and communicated by W. W. Fisher.

Turbid, containing some clay in suspension. No odour. Appearance in 2-ft. tube, bluish-grey.

	In grains per gallon.
Total dissolved solid matter	64·
Chlorine in chlorides	1·7
Ammonia, free and saline	·015
Albuminoid ammonia	·008
Nitrogen in nitrates	·091
Nitrogen in nitrites	0
Oxygen required to oxidise organic matter, in 3 hours	·054
Hardness	42·7°

Marston, cont.

Contains some excess of dissolved solids, but the other constituents are normal in amount. The mineral matter in solution consists largely of sulphate and carbonate of lime. Perhaps after a time the water will be less hard. An unpolluted water, fit for drinking and domestic use.

2. Public Supply.

Made and communicated by Dr. J. C. Thresh. February, 1916.

Trace of oxide of iron. Faint green. No odour. Reaction neutral.

In parts, per 100,000.

		Probable combinations:—	
Ca	21·1	Calcium carbonate	37·5
Mg	3·	Calcium sulphate	20·7
Na	8·10	Magnesium sulphate ...	14·8
Fe	trace.	Sodium sulphate	21·6
CO_3	22·5	Sodium chloride	4·1
SO_4	41·	Sodium nitrate ...	1·5
Cl	2·5	Silica, oxide of iron, etc. ...	2·
NO_3	1·1		
		Total solid constituents dried at 180° C....	102·2

Free ammonia	·0020
Organic ammonia	·0048
Oxygen absorbed in 3 hours at 37° C. ...	·0500
Nitrites	nil.

Hardness: Temporary, 33°; Permanent, 33° · Total, 66°.

Missenden, Great.

W. W. Fisher, *Analyst*, August, 1901.

	In grains per gallon.
Total solids	22·1
Chlorine in chlorides	·77
Nitrogen in nitrates	·21
Ammonia	·003
Albuminoid ammonia	·001
Oxygen absorbed in 3 hours	·007

Newport Pagnell.

Well 50 ft. deep. Water from Great Oolite. *see* p. 150.

By W. W. Fisher.

A.—*Analyst*, 1904, vol. xxix, No. 335, p. 30.

B.—Sample taken 10th June, 1910 (from Local Government Board).

C.—Received February 14th, 1912 (Local Government Board).

In grains per gallon.

	A	B	C
Total solids	32·2	35·56	42·56
Chlorine in chlorides	1·4	1·7	1·8
Nitrogen in nitrates	·203	·14	·497
Nitrogen in nitrites...	—	0	0
Saline ammonia	·0	·004	0
Albuminoid ammonia	·006	·007	·004
Oxygen absorbed in 3 hours	·01	·019	·016
Hardness	25°		

B.—Contains a moderate amount of dissolved mineral constituents. The quantities of chlorides and nitrates are small, and also the proportion of organic matter.

An unpolluted supply of satisfactory quality, but rather hard.

C.—The total quantity of dissolved solids has risen about 5 [? 7] grains since 1910, and the water is proportionally harder. The chlorides have changed but little, but the nitrates are distinctly larger. The proportion of organic matter remains small.

Oakley.

1. From a well 50 ft. deep at Addingrove Farm ?

2. From a boring of 27½ ft. at Addingrove Farm, in field 434 of the Ordnance Map. Water overflows at the rate of 6 gallons a minute.

Water from Ampthill Clay ?

Analyses made and communicated by W. W. Fisher.

	In grains per gallon.	
	1	2
Total solids	442·	108·
Chlorine in chlorides	37·2	6·
Ammonia, free	·084	·042
Ammonia, albuminoid	·007	·006
Nitrogen as nitrates	·224	·03
Oxygen absorbed	·084	·043

1. Much sulphate of lime.

2. Very alkaline (carbonate of soda 35, sulphate of soda 50, chloride of sodium 10).

Pounden.

1. Pounden Hill, 209 ft. deep, *see* p. 156.

By W. W. Fisher. February, 1905. Latter part 1908. Sample slightly cloudy. Residue on evaporation alkaline. Odour none. Colour in 2-ft. tube pale yellowish.

	In grains per gallon.
Total dissolved solid matter, dried at 180° C.	77·84
Chlorine in chlorides	5·3
Ammonia, free and saline	·036
Ammonia, albuminoid	·003
Nitrogen in nitrates	·02
Nitrogen in nitrites	0
Oxygen required to oxidize organic matter (in 3 hours)	·039

The mineral constituents consist mainly of alkaline compounds, and, as the proportion of lime is small, the water is soft. The proportion of organic matter is very small. The water is an unpolluted natural supply of normal composition, such as is usually found in the Oolites below the Oxford Clay. It is suitable for drinking and domestic purposes.

The chief constituents are as follows.

Chlorine	5·3
Sulphuric acid, SO_3	19·41
Carbonic acid, CO_2	14·47
Lime, CaO	1·19
Magnesia, MgO	·48
Soda, calculated as Na_2O	37·96
Silica	·84

Traces of iron not estimated. The soda contains traces of potash.

These may be assumed to be combined as below—

Sodium chloride	8·73
Sodium sulphate, dry	34·45
Sodium carbonate	31·27
Magnesium carbonate	1·
Calcium carbonate	2·12
Silica	·84
Total	78·41

The total residue by evaporation is 77·84, and the difference is due to a slight loss of carbonic acid from the magnesium carbonate.

Waters of this (soft, alkaline) type are usually found in parts where Oxford Clay overlies the Oolitic beds containing water.

Pounden, cont.

The water is not too salt for general domestic purposes, and it will probably become less alkaline when the well has been in use for a time and the soluble constituents are removed.

For another analysis, *see* table, p. 281.

2. New well (? 1898) near village.

Made and communicated by Dr. J. C. Thresh, May, 1898.

Turbid. Colourless. Excessively hard and contains too much organic matter.

	In parts per 100,000.
Chlorine	1·7
Equivalent to chlorides	2·8
Nitric nitrogen	·1
Equivalent to nitrates	·6
Nitrates	nil
Free ammonia	·008
Organic ammonia	·015

Hardness: Permanent, 24·2°; Temporary, 32·9°; Total, 57·1°.

Rowsham, *see* Wingrave, p. 306.

Shenley Church End.

The Rectory. New well. *See* p. 157.

Made (January, 1909) and communicated by W. W. Fisher.

	In grains per gallon.
Sodium chloride	21·1
Sodium sulphate	6·46
Magnesium sulphate	16·64
Calcium sulphate	74·28
Calcium carbonate	9·5
Total	127·98

Slapton.

A.—Water from an old well. B.—Water from boring 22½ ft.

Two analyses made (March 1910) and communicated by W. T. Burgess.

	In parts per 100,000. A	B
Total solid residue	75·36	64·52
Ammonia, free	0	·004
Ammonia, albuminoid	·0085	·030
Nitrogen as nitrates	2·014	·750
Nitrogen as nitrites	0	0
Oxygen absorbed in 4 hours at 80° F.	·107	·255
Chlorine	5·2	4·
Total lime (CaO)	24·	23·4
Total magnesia (MgO)	2·2	1·9
Total carbonates, calculated as carbonate of lime	30·4	33·6
Total hardness, calculated from lime and magnesia	48·5	46·5

A.—Slightly turbid. B.—Very turbid.

Slough.

A.—Well 211 ft. deep. By W. W. Fisher, *Analyst*, August, 1901.
B.—Eton Union. Also by W. W. Fisher. An excellent water.

	In grains per gallon. A	B
Total solids	22·68	21·84
Chlorine in chlorides	1·	1·05
Nitrogen in nitrates	·21	·03
Ammonia	·025	·032
Albuminoid ammonia	·005	·003
Oxygen absorbed in 3 hours	0	·005

Slough, cont.

C.—Slough Motor Transport Depot, from Gravel, *see* p. 159.

Proc., Geol. Assoc., vol, xxxi, pt. 3, 1920, p. 134; and further details from W. H. Booth.

By E. W. Lucas, Messrs. Griffith and Walden, of Slough, August 7th, 1919.

	In grains per gallon.
Total solid matter, dried at 212° F.	28·
Carbonate of lime	15·7
Carbonate of magnesia	·3
Sulphate of lime	4·4
Chlorine	1·4
Saline ammonia	·0007
Albuminoid ammonia	·0042
Nitrogen as nitrates	·5185
Nitrites	absent.
Oxygen consumed in 3 hours	·012
Poisonous metals	absent.

Hardness, by soap-test: temporary 13·5°, permanent 3·5°, total 19° (given as 20° in one account).

Appearance in two-foot tube, clear.

"From the chemical point of view the water should prove wholesome."

D.—Slough Motor Transport Depot. Water from the Chalk, when the boring was 302 ft. down. Communicated by W. H. Booth.

By E. W. Lucas, Messrs. Griffith and Walden, of Slough.

	In grains per gallon.
Total solid matter, dried at 212° F.	21·
Chlorine	1·4
Saline ammonia	·007
Albuminoid ammonia	·0014
Nitrogen as nitrates	·3169
Nitrites	absent.
Oxygen consumed in 3 hours	·0031
Poisonous metals	absent.

Total hardness 15°.

Appearance in two-foot tube, slightly turbid.

"There was a slight deposit of mineral and vegetable debris containing low forms of life . . but, from the chemical point of view, the supply should prove wholesome . . if suitably clarified." Mr. Booth says that the deposit was probably derived from the pipes, trough, etc., which were not fully cleaned. Moreover this water was not pumped very much.

Stoke Hammond.

Ordnance Map 220, new ser. (Bucks. 20, NW.). Geologic Map 46, NW.

Well 50 ft. deep.

Made and communicated by Dr. J. C. Thresh, January, 1898.

Dull. Yellow. Very hard and contains an excessive amount of saline matter. Unsuited for domestic use.

	In parts per 100,000.
Total solid matter, dried at 180° C.	130·
Chlorine	4·6
Equivalent to chlorides	7·7
Nitric nitrogen	·06
Equivalent to nitrates	·36
Nitrates	nil
Iron	trace
Free ammonia	·012
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C.	·168

Hardness: Permanent, 20°; Temporary, 14·3°; Total, 34·3°.

Stokenchurch.

Public Well, *see* p. 162.

Made and communicated by W. W. Fisher.

	In grains per gallon.
Total solids	35·
Chlorine in chlorides	1·7
Free ammonia	0
Albuminoid ammonia	·001
Nitrogen in nitrates	·728
Oxygen absorbed in 3 hours	·016
Nitrates above the normal	

Stony Stratford (*see* p. 163).

Water from Great Oolite.

A.—W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 30.

B.—Water Works Directory, 1911, p. 346.

C.—Sample received 21st August, 1911. From Local Government Board.

	In grains per gallon.		
	A	B	C
Total solids	38·9	40·04	46·2
Chlorine in chlorides	2	2·65	2·3
Nitrogen in nitrates	·45	·065	·756
Nitrogen in nitrites	—	0	0
Saline ammonia	·005	·002	0
Albuminoid ammonia	·003	·006	·003
Oxygen absorbed in 3 hours ...	·012	·005	·012

B.—"The total amount of dissolved solids has not changed since the last analysis in April 1907, but both the chlorides and nitrates have somewhat increased . . . the water is of satisfactory quality."

Hardness: Permanent, 6°; Temporary, 18°; Total, 24°.

Clear and bright. No odour. Pale bluish tint in two-foot tube.

C.—Total mineral constituent somewhat larger than in 1907, and the chlorides have slightly increased. The proportion of organic matter remains small. The water is unpolluted and of satisfactory quality. A gradual rise in the mineral solids, chlorides and nitrates, seems to be taking place, and the water is consequently becoming harder.

Another analysis is of much the same character.

Turweston.

Boring, *see* p. 165.

Made and communicated by Dr. J. C. Thresh. 1906.

	In parts per 100,000.	Probably combined as—	
Ca	10·2	Calcium carbonate	25·5
Mg	·55	Magnesium carbonate ...	1·9
Na	7·25	Sodium carbonate	5·85
CO_3	19·95	Sodium sulphate	8·95
SO_4	6·05	Sodium chloride	4·6
Cl	2·8	Silica, etc.	1·9
NO_3	trace		
		Total solids...	48·7

Hardness permanent, 4°; temporary, 22°; Total, 26°.	
Free ammonia	·004
Albuminoid ammonia	·0034
Nitrites	nil

For an analysis of the water of the public supply, *see* table, p. 281.

Twyford.

1. Trial-boring 30 ft. deep. Mrs. Fitzgerald's. Water from Kellaways Beds or Oxford Clay ?

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 32.

2. Twyford Manor (? Lodge). Water from Drift ?

	In grains per gallon.	
	1	2
Total solids	241·	32·
Chlorine in chlorides	23·4	1·4
Nitrogen in nitrates	·035	0
Saline ammonia	·07	·001
Albuminoid ammonia	·018	·245
Oxygen absorbed in 3 hours	·133	·003

Much sulphate of lime.

3. Shallow well in the village.

Made and communicated by Dr. J. C. Thresh, December, 1897.

Slightly dull. Yellow. Contains too much organic matter.

	In parts per 100,000
Chlorine	2·4
Equivalent to chlorides	4·
Nitric nitrogen	·54
Equivalent to nitrates	3·2
Nitrites	nil
Free ammonia	·008
Organic ammonia	·028

Hardness: Permanent, 6·4°; Temporary, 4·3°; Total, 10·7°.

For an analysis of the water of the public supply, *see* table, p. 281.

Westbury.

Ordnance Map 219, new ser. (Bucks. 12, NE.). Geologic Map 45, NE.

Well at Manor, on the lawn.

Made and communicated by W. W. Fisher.

Water from Great Oolite.

	In grains per gallon.
Total solids	29·4
Chlorine	1·
Ammonia	·001
Albuminoid ammonia	·004
Nitrogen as nitrates	·161
Oxygen absorbed	·005

Good water. Another analysis (? from same well) in the table on p. 282.

Westcott.

Ordnance Map 237, new ser. Geologic Map 45, SE.

Well 185 ft. deep. Water from Corallian Oolite below Kimmeridge Clay.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 33.

	In grains per gallon.
Total solids	76·
Chlorine in chlorides	1·4
Nitrogen in nitrates	·112
Saline ammonia	·002
Albuminoid ammonia	·01
Oxygen absorbed in 3 hours	·074

Hard. Sulphate of lime.

Whitchurch.

Ordnance Map 219, new ser. (Bucks. 23, SE.). Geologic Map 46, SW.

Two wells.

A.—12 ft. deep. Water from Kimmeridge Clay.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 33.

In grains per gallon.

	A	B
Total solids	174·	96·
Chlorine in chlorides	10·1	1·2
Nitrogen in nitrates	·42	·014
Saline ammonia	·003	·005
Albuminoid ammonia	·006	·007
Oxygen absorbed in 3 hours ...	·025	·037

B.—Hard. Sulphate of lime.

Wing.

1. Vicarage Lane. 2. Church Road.

Communicated by Dr. J. C. Thresh.

In grains per gallon.

	1	2
Chlorine in chlorides	8·4	10·9
Nitrogen in nitrates	4·	4·4
Permanent hardness	18°	19°
Temporary hardness	14°	13°
Free ammonia	·08	·02
Organic ammonia	·12	·08
Oxygen absorbed in 15 minutes at 212° F.	1·4	1·08

3. Church End Well.

Made and communicated by Dr. J. C. Thresh, December, 1898.

Clear. Very slightly yellow.

In parts per 100,000.

Chlorine	15·6
Equivalent to chlorides	26·
Nitric nitrogen	6·3
Equivalent to nitrates	37·8
Nitrites	nil
Free ammonia	·002
Organic ammonia	·008

Hardness: Temporary, 18·6°; Total, 45·7°.

Derived from a greatly polluted subsoil. An excessive amount of chlorides and nitrates. Effect of percolation most marked, practically all the organic matter fully oxidized.

Wing, *continued.*

Public Supply, *see* p. 167. Made and communicated by Dr. J. C. Thresh. In parts per 100,000.

1906.	Source of sample.	Cl.	N.	Hardness.			Ammonia.		Oxygen absorbed.
				Temporary.	Permanent.	Total.	Free.	Albuminoid.	
September 27	Small trial-bore	4·7	·05	9°	20°	29°	·012	·04	·036
October 9	Final bore, at 75 ft. ...	4·6	·03	18°	32°	50°	·001	·016	·448
October 16	Final bore, at 90 ft. ...	4·4	1·4	16°	18°	34°	·001	·006	·056
November 13	Final bore, at 120 ft. ...	5·	1·3	10°	21°	31°	·000	·006	·024
December 19	Final bore, 120 ft., after 14 days' pumping ...	3·	·6	7°	8°	15°	·000	·018	·237

The differences in the samples at different levels are very curious. *See also* under Linslade, No. 3, p. 294.

Wingrave.

Hamlet of Rowsham.

Well 12 ft. deep. Water from Lower Greensand. Hard.

W. W. Fisher, *Analyst*, July, 1902.

In grains per gallon.

Total solids	95·
Chlorine in chlorides	2·5
Nitrogen in nitrates	·021
Saline ammonia	·005
Albuminoid ammonia	·005
Oxygen absorbed in 3 hours	·008

Winslow.

Water from a covered well. No particulars given, May 1902.

Made and communicated by W. T. Burgess.

In parts per 100.000

Total solid residue	82·84
Organic carbon	·217
Organic nitrogen	·022
Ammonia, free	·001
Ammonia, albuminoid	·007
Nitrogen as nitrates	·028
Nitrogen as nitrites	0
Total combined nitrogen	·051
Oxygen absorbed in 4 hours at 80° F.	·064
Chlorine	5·5

Hardness, total (by soap-test) 42·8, permanent 8·3, temporary 34·5.

Turbid.

Wolverton.

London and North Western Railway. By the parish-boundary with Bradwell.

Used for public supply. *See* p. 169.

From the newer boring, near the older boring, but larger.

Analysed and communicated by W. W. Fisher.

In grains per gallon.

Total solids	56·28
Chlorine	1·9
Ammonia	·003
Albuminoid ammonia	·007
Nitrogen as nitrates	·042
Oxygen absorbed	·022

Total hardness, 42°; permanent, 21·9°.

Made November, 1913. From the Local Government Board.

In parts per million.

Total solid matter in solution	732·
Chlorine	29·
Free ammonia	·01
Albuminoid ammonia	.05
Oxygen used by organic matter	·85

Hardness: 35·7°, Clark's scale.

Wooburn.

Bourne End. Works of the Marlow Water Co. *See* p. 169.

Made and communicated by W. W. Fisher.

Excellent water.

In grains per gallon.

Total solids	21·84
Chlorine as chlorides	·9
Ammonia, free	0
Ammonia, albuminoid	·001
Nitrogen as nitrates	·01
Oxygen absorbed in 3 hours	·005

Wotton Underwood.

Ordnance Map 237, new ser. (Bucks. 27, E.). Geologic Map 45, SE.

Woodburn Cottages.

Well 14 ft. deep. Water from Kellaways Beds or Oxford Clay.

W. W. Fisher, *Analyst*, 1904, vol. xxix, No. 335, p. 32.

	In grains per gallon.
Total solids	753·
Chlorine in chlorides	90·3
Nitrogen in nitrates	·035
Saline ammonia	·005
Albuminoid ammonia	·007
Oxygen absorbed in 3 hours	·064

Wycombe.

1. Wycombe Marsh Mills.

Made and communicated by Dr. J. C. Thresh. December, 1914.

A trace of turbidity, due to iron-oxide, etc. Faint yellow-green. No odour Reaction neutral.

In parts per 100,000.

		Probable combinations :—	
Ca	10·25	Calcium carbonate	24·6
Mg	·05	Calcium sulphate	1·55
Na	2·5	Magnesium sulphate ...	·25
Fe	·05	Sodium sulphate	2·95
CO_3	14·8	Sodium chloride	2·3
SO_4	3·3	Sodium nitrate	2·45
Cl	1·4	Silica, iron-oxide, etc. ...	1·7
NO_3	1·8		
		Total solid constituents, dried at 180° C....	35·8

Hardness : Temporary, 22·5°; Permanent, 2·5°; Total, 25°.

Free ammonia	·004
Organic ammonia	·0052
Oxygen absorbed in 3 hours at 37° C. ...	·062
Nitrites	nil.

2. Waterworks. *See* p. 170.

A.—Sample taken 19th October, 1909.

B.—Sample taken 30th April, 1911.

By C. E. Cassal. From the Local Government Board.

In both. Appearance in two-foot tube, clear, very faint greenish tint. Odour and taste not abnormal.

In A, reaction neutral.

	In parts per 100,000. A	B
Total solid matters	34·4	34·6
Saline ammonia	·0006	·0008
Organic ammonia	·001	·062
Nitrogen as nitrates	·225	·175
Nitrites	absent.	absent.
Oxygen absorbed from permanganate at 30° C. in 4 hours	·0259	·0079
Chlorine as chloride (chloride of sodium 2·14) ...	1·3	1·3
Phosphates	very faint traces.	very faint traces.
Lead and iron	absent.	absent.
Mineral analysis :—		
Lime (CaO)	12·28	14·6
Magnesia (MgO)	1·27	1·51
Sulphates (as SO_3)	·6	·85

Microscopic examination of the suspended matters :—In both a little mineral matter. No living organism.

An analysis in the Water Works Directory, 1911, p. 85, seems to be the same as *A* : but there are some small differences in the figures, and the following are added :—Organic carbon ·007 and Organic nitrogen ·003.

Hardness,	total	23·4	23·6
,,	permanent	2·8	2·4
,,	temporary	20·6	21·2

Analyses of Waters from Wells in Drift (Gravel and Sand). Made and communicated by W. W. FISHER. In grains per gallon.

Locality, and Ordnance Map.	Depth of well, in feet.	Total Solids.	Chlorine in Chlorides.	Free Ammonia.	Albuminoid Ammonia.	Nitrogen in Nitrates.	Oxygen absorbed in 3 hours.	Remarks.
Addington. A new well, 219 ...	20 ?	33·9	1·1	·003	·008	·07	·049	In sand.
Chetwode. Sunflower Farm, for cottage-supply, 219	—	48·	·6	·011	·01	·02	·056	—
Claydon, East. House in village, 219	34	113·	2·7	·001	·002	·063	·016	Much lime-sulphate.
Claydon, East. Botolph Claydon, 219	—	43·	1·3	0	·003	·014	·029	—
Claydon, Middle. Sandhill, ¼ mile from buildings, 219...	12 ?	24·	·8	·004	·008	·336	·025	Clay (and soil) 5 ft., to gravel.
Cublington. Trial-boring No. 1 (school), 220	37 ?	68·	3·8	·006	·006	·028	·044	Clay with chalk-stones, 29 ft., to dry sand. Water at 37 ft.
Dunton, near. Trial-boring, 219, 220	67	114·	9·6	·043	·006	·07	·025	—
Fulmer. 255	—	8·7	2·6	·001	·003	·033	·017	Very soft.
Horwood, Great. High Street. Top well, for public supply, 219 ...	—	53·	8·3	·003	·009	·028	·188	Not satisfactory. Excess of organic matter.
Horwood, Great. Roddimore Farm, south of village	12	34·	2·	·003	·007	·04	·033	Loam 3 ft., clay 3, sand 6.
Horwood, Great. Singleborough. Pear-tree Villa	—	56·	3·7	·001	·006	·14	·058	—
Lillingstone Lovell. Home Farm, 202	29	119·	17·	·004	·001	·014	·016	Clay with stones and veins of sand [Boulder Clay], 29 ft. Water rises about 12 ft. Plentiful supply.

Analyses of Waters from Wells in Drift (Gravel and Sand).—continued.

Locality, and Ordnance Map.	Depth of well, in feet.	Total Solids.	Chlorine in Chlorides.	Free Ammonia.	Albuminoid Ammonia.	Nitrogen in Nitrates.	Oxygen absorbed in 3 hours.	Remarks.
Loughton. By roadside toward Shenley, 220	30	118·	9·4	·14	·007	·04	·058	15 ft. of water. Complaints of smell and rust.
Mursley, Salden, north-east of village, 220	15	61·	·63	·003	·015	·028	·1	Excess of lime-sulphate and organic matter.
Newton Longville. Old stone-lined well. Water taken in a pipe for over half a mile, 220	13	52·	2·7	·003	·01	·1	·051	Excess of lime-sulphate.
Oving. New building site, 219 ...	27	68·	3·8	·049	·007	·03	·053	Clearly polluted.
Shenley Church End. School. Trial-boring (Bucks. Education Committee) 220.	20	102·	4·4	·028	·007	·67	·029	20 ft. of clay, to sand.
Stewkley. Trial-boring, 220... ...	55	131·	7·1	·04	·003	·03	·019	Through clay and few veins of sand.
Stoke Hammond. Stoke Lodge, 220	25	65·	4·6	·003	·006	·035	·032	—
Wavendon. Manor Fields, on the southern slope of the hill. 290 ft. above O.D., 220	40	92·	1·9	·001	·003	·014	·013	[The source may be Oxford Clay.]
Wingrave. Vicarage, 238	14 ?	53·	2·4	·01	·007	·056	·027	14 ft. of clay, to sand.

ANALYSES OF WELL-WATERS. HERTFORDSHIRE.

Aldbury.

1. Tring Railway Station, *see* p. 173.

By R. Phillips. 1849.

Proc. Inst. C. E. 1849, vol. viii, p. 172, and 1850, vol. ix, p. 177. Gen. Bd. Hlth. Report on the Supply of Water to the Metropolis. Appendix ii, table opp., p. 93. 1850.

	In grains per gallon.	
Carbonate of lime	14·72	Total 18·8
Sulphate of lime	1·09	
Muriate of soda	1·38	
Carbonaceous matter	1·61	

2. 3. Later analyses. By J. C. Tipler. From the Local Government Board. Water from delivery-pipe from pump at station. 2nd September, 1911. 3rd November, 1912.

Preliminary examination (2). Suspended matter, none. Colour, equal to distilled water. Odour, very slightly earthy. Nitrogen as nitrates, 10 parts per million. Nitrogen as nitrites, absent. Poisonous metals, absent. Reaction, slightly alkaline.

	In parts per million. (2)	(3)
Total solid matter in solution	410·	426·
Chlorine	24·	24·
Free ammonia	·01	·01
Albuminoid ammonia	·01	·03
Oxygen used by organic matter	·17	·26
Hardness, Clark's scale 20·2°, 20·8°	—	—

Amwell, Great.

1. ? Amwell Hill Pumping Station. *See* p. 174.

R. Comm. Water Supply. Appendix. 1869, p. 104.

(? By Frankland and Odling.)

	In parts per 100,000.
Total solid residue, dried at 100° C. ...	31·88
Lime	14·1
Magnesia	·86
Potash	·46
Soda	1·28
Sulphuric acid	1·68
Carbonic acid	11·35
Silica	1·36
Chlorine	1·39
Nitrogen as nitrates and nitrites	·406
Ammonia	·000
Organic nitrogen	·009
Organic carbon	·076
Hardness before boiling (total)	22·4
Hardness after boiling (permanent) ...	5·9

The following particulars are added from Sixth Report of Rivers Pollution Commission, 1874, p. 100:—

Clear and palatable. Temperature 11° Centigrade.

2. Amwell Hill Well.

By A. J. Bernays, 1878. Sample taken 8th July.

Slightly turbid from suspended matters. Sediment brownish, ferruginous. Residue white, granular. Under the microscope a few *infusoriæ* and *diatomaceæ*.

Potassium oxide	·18
Sodium oxide	·54

Amwell, cont.

Calcium oxide	8·54
Magnesium oxide	·55
Chlorine	·93
Sulphuric anhydride	1·5
Nitric anhydride	·903
Carbonic anhydride	6·4
Silica	1·01
Iron and alumina	·46
Probably combined as	
Calcium carbonate	14·
Magnesium carbonate	·46
Potassium sulphate	·34
Sodium chloride	1·03
Sodium sulphate	·62
Calcium sulphate...	1·7
Silica	1·01
Magnesium nitrate	1·23
Ferric oxide and alumina	·46
Total	20·85
Total residue given as	21·14
Free ammonia	·0014
Albuminoid ammonia	·0031
Nitrogen as nitrates	·234
Organic carbon, per gallon	·062
Organic nitrogen, per gallon	·023

Hardness before boiling, 16·09; after boiling, 2·74.

3. Amwell Marsh Well. New River Co., now Metropolitan Water Board. *See* p. 174.

Made and communicated by Dr. J. C. Thresh, May, 1899.

		Probable combinations:—	In parts per 100,000.
Ca	11·9	Calcium carbonate	22·
Mg	·55	Calcium sulphate	3·55
Na	1·55	Magnesium sulphate	1·
CO_3	13·2	Magnesium chloride	1·4
SO_4	2·5	Sodium chloride...	·9
Cl	1·6	Sodium nitrate	4·25
NO_3	3·25	Silica, etc.	·4
		Total solid constituents, dried at 180° C.	33·5
		Free ammonia	·000
		Albuminoid ammonia	·004
		Oxygen absorbed in 3 hours at 37° C. ...	·041
		Nitrites	nil

Hardness: Permanent, 9°; Temporary, 19°; Total, 28°.

4. In the Report of G. Rennie on the Supply of Water from the District of Bagshot, 1850, pp. 25, 26, are the following particulars of the waters of two of the New River Co.'s. wells :—

Amwell End well. Hardness, Clark's scale, 13·8°. Sample of mixed waters, taken 12 ft. below the top of the Chalk, temperature 56°.

Amwell Hill well. Hardness, Clark's scale, 13·8°. Sample from 50 ft. down (or 40 ft. above the main spring), temperature 52°.

5. *A.*—Home Lodge. *B.*—Vicarage.

Samples taken 7th June, 1878.

By A. J. Bernays.

A.—Contained a number of water-fleas. On evaporation the smell was marsh-like. Residue white, granular; blackened on ignition.

B.—Free from life. Residue white and granular; browned on ignition.

Evidence of slight contamination in both.

Amwell, cont.

	A	B
Potassium oxide	·29	·35
Sodium oxide	1·02	·77
Calcium oxide	6·08	4·59
Magnesium oxide	·95	·33
Chlorine	·85	·64
Sulphuric anhydride	2·2	1·54
Nitric anhydride	·72	·8
Silica	trace	trace
Probable combinations:—		
Carbonate of lime	8·85	6·98
Carbonate of magnesium	1·43	·06
Sulphate of potash	·54	·66
Sulphate of soda	·63	·49
Sulphate of lime	2·72	1·65
Chloride of sodium	1·4	1·05
Nitrate of magnesia	·99	1·1
Total	16·56	11·99
Solid residue at 110° C. given as ...	17·57	11·9
Free ammonia	none	none
Albuminoid ammonia	·0073	·0056
Organic carbon	·146	·178
Organic nitrogen	·041	·053

Hardness, before boiling, 12·65° and 9·67°; after boiling 3·63° and 3·95°.

Ashwell.

Well made for the Rural District Council. *See* p. 176.

Made and communicated by Dr. J. C. Thresh, 1911.

		Probably combined as—	In parts per 100,000.
Ca	10·2	Calcium carbonate	21·7
Mg	·3	Calcium sulphate	1·85
Fe	0	Calcium chloride	2·65
Na	1·	Magnesium chloride	·65
CO_3	13·	Magnesium nitrate	1·05
SO_4	1·3	Sodium nitrate	3·65
Cl	2·2	Etc.	1·48
NO_3	3·5		
		Total solid constituents dried at 180° C. ...	33·03

Hardness: Temporary, 7°; total, 24°.

Free ammonia	·001
Organic ammonia	·002
Oxygen absorbed in 3 hours at 37° C. ...	·624
Nitrites	nil

Clear and bright. A trace of chalk deposited (perhaps because the engine was driving the pump at a much higher speed than usual, just before the sample was taken).

Faint green. Odour none. Reaction neutral.

Organically the water is of the highest degree of purity.

Ayot.

Water from well, 179 ft. deep, possibly 40 ft. into Chalk.

Made (Dec. 1912) and communicated by W. T. Burgess.

	In parts per 100,000.
Total solid residue	38·96
Organic carbon	·031
Organic nitrogen	·004
Ammonia, free	·002
Ammonia, albuminoid	·002
Nitrogen as nitrates	·753
Nitrogen as nitrites	0
Oxygen absorbed in 4 hours at 80° F.	·011
Chlorine	1·75
Total carbonates, calculated as carbonate of lime ...	26·7

Hardness, total (by soap-test), 27·5°; permanent 3·9°; temporary 23·6°.

Barnet District Water Co.

From a domestic tap. From the Local Government Board. 1913 or earlier.

	In grains per gallon.
Total dissolved matter	26·32
Loss on incineration of residue	2·52
Chlorine in chlorides	2·4
Equal to chloride of sodium	3·95
Nitrogen in nitrates	·05
Equal to nitric acid	3·19
Free (actual or saline) ammonia	·001
Albuminated (organic) ammonia	·001
Oxygen absorbed from solution of permanganate of potash at 80° F. in 15 minutes...	·005
Ditto in 4 hours	·008
Phosphoric acid	traces

Hardness before boiling, 20°; after boiling, 5½°.

A water of a very high degree of purity, as regards freedom from contamination. This is shown also by bacteriologic examination.

Berkhamstead.

Waterworks. *See* p. 187.

1. Made and communicated by Dr. J. C. Thresh. 1899.

Clear and Colourless.

		Probable combinations.	In parts per 100,000.
Ca	8·9	Calcium carbonate	20·25
Mg	·0	Calcium sulphate	·45
Na	·85	Calcium nitrate	2·4
CO_3	12·15	Sodium chloride	2·15
SO_4	·3	Silica, etc.	1·25
Cl	1·3		
NO_3	1·8	Total solid constituents, dried at 180° C.	26·5

Hardness: temporary, 16° (another account gives 19°); permanent, 4°; total, 20°.

Free ammonia	·000
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C.	·037
Nitrites	Nil

2. Another analysis, by Messrs. Allen and Hanbury. March, 1910.

From the Local Government Board.

Colour in 2-ft tube, pale blue, clear. No smell.

	In grains per gallon.
Total dissolved solids	22·4
Loss on ignition (organic matter), etc.	3·9
Mineral matter	18·5
Chlorine ·99, equal to sodium-chloride	1·6
Lead, copper, iron	Nil
Nitrogen as saline ammonia	·0011
,, albuminoid ammonia	·0022
,, nitrites	Nil
,, nitrates	·196
Oxygen absorbed by organic matter at 27° C., in 15 minutes	·0028
Oxygen absorbed by organic matter at 27° C., in 4 hours	·0168

Hardness before boiling 13°; after boiling (permanent) 3°.

This water is free from any evidence of animal pollution, and the figures show a satisfactory degree or organic purity. It is a good supply.

3. A later analysis. December, 1913.

By A. Hill. (The British Drug Houses.)

From the Local Government Board.

A clear colourless water. No sediment and no moving organisms. Reaction alkaline.

Total solids	21·	grains per gallon.
Chlorine	·9	

Berkhamstead, cont.

Free ammonia	·012	parts per million.
Albuminoid ammonia	·018	
Nitrogen as nitrates	4·115	
Nitrites, phosphates, heavy metals	absent.	

Total hardness, 14·5°; permanent, 3°; calculated as $CaCO_3$

A good class water, well adapted for drinking purposes.

Bishop's Stortford.

Public Supply. *See* p. 193.

Made and communicated by Dr. J. C. Thresh.

A.—December, 1897.

B.—October, 1905.

	A	B	Probable combinations:	In parts per 100,000. A	B
Ca	11·8	12·	Calcium carbonate ...	26·5	28·2
Mg	·5	·45	Calcium sulphate	4·	2·5
Na	·6	—	Magnesium chloride ...	2·	1·75
CO_3	15·9	16·9	Sodium chloride	·5	1·
SO_4	2·8	1·75	Sodium nitrate	1·4	1·6
Cl	1·8	1·9	Silica, etc.	2·6	·95
NO_3	1·	1·15			
	Total solid constituents dried at 180° C.			37·	35
	B.—Total hardness 32°.				
	A.—Free ammonia			·0025	—
	„ Organic ammonia			·003	—
	„ Nitrites			Nil	—

A Report at the Local Government Board gives the temporary hardness at 21·6° and the permanent as 5°.

Broxbourne.

Works of the Ware Rural District Council. *See* p. 196.

By Dr. B. Dyer.

Sample taken October, 1912.

From the Local Government Board.

	In grains per gallon.
Total dissolved matter	22·12
Loss on incineration of residue	2·24
Chlorine in chlorides (equal to sodium-chloride 2·47) ...	1·5
Nitrogen in nitrates (equal to nitric acid ·42)	·11
Free (actual or saline) ammonia	·001
Albuminoid (organic) ammonia	·001
Oxygen absorbed by organic matter, etc., from a solution of permanganate of potash at 80° F. in 15 minutes ...	·008
Ditto in 4 hours	·015
Phosphoric acid	trace.

This water gives no indication of any objectionable impurities.

Buntingford.

Waterworks. *See* p. 196.

By A. E. Ekins. May, 1911.

From the Local Government Board.

	In grains per gallon.
Total solids	25·
Chlorine	1·15
Free ammonia	·0008
Albuminoid ammonia	·0004
Nitrogen as nitrates, etc.	·31
Nitrites	absent.
Oxygen absorbed in 15 minutes at 80° F.	·017
„ „ 4 hours at 80° F.	·045

This water was clear and bright and the solids experienced no discoloration on ignition. This is of a high degree of organic purity.

Bushey.

Colne Valley Waterworks. A. B. C. January, 1913.
A.—Well of 1885. Sample taken at 5 p.m.
B.—Well of 1887. Sample taken at 12 noon.
C.—Well of 1902. Sample taken at 11.15 a.m. About 40 ft. below water-level.
D.—Eastbury Well (in Watford). May, 1912, 2.10 p.m. 100 ft. down.
E.—Eastbury Well. January 1913, 3.35 p.m.
Made and communicated by Dr. J. C. Thresh.
A.—Clear and bright. No matter in suspension. Very faint yellow. Reaction neutral.
B.—Dull, whitish opalescence. Whitish. Reaction neutral.
C.—Clear and bright. No suspended matter. Very faint yellow. Reaction neutral.
D.—Clear and bright. Excellent appearance. Very faint yellow. No odour. Reaction neutral.
E.—Clear and bright. A few specks of dirt. Very faint yellow. No odour. Reaction neutral.

	A	B	C	D	E
Ca	11·2	11·2	12·25	11·5	11·4
Mg	·8	·45	·5	0	·4
Na	2·42	1·22	1·65	2·71	1·93
CO_3	16·8	15·3	15·6	15·6	15·
SO_4	3·3	2·4	5·35	4·2	4·6
Cl	2·45	1·9	1·9	2·	2·15
NO_3	2·05	2·26	2·52	1·8	1·9

In parts per 100,000.

Probable combinations :—	A	B	C	D	E
Calcium carbonate	28·	25·5	26·	26·	25
Calcium sulphate...	—	3·4	6·29	3·74	4·76
Magnesium sulphate	3·95	—	1·14	—	1·55
Magnesium chloride	—	1·76	1·06	—	·35
Sodium sulphate	·22	—	—	2·31	—
Sodium chloride	4·04	·97	1·83	3·29	3·12
Sodium nitrate	2·81	3·1	3·45	2·47	2·6
Etc.	·98	1·27	·23	·19	·62
Total solid constituents dried at 180° C.	40·	36·	40·	38·	38·
Hardness { Temporary	22°	22°	25°	19·5°	20·6°
Hardness { Permanent	7°	6°	8°	6·5°	8·°
Hardness { Total	29°	28°	33°	26°	28·6°
Free ammonia	·066	·060	·060	·003	·003
Organic ammonia	·003	·004	·016	·002	·004
Oxygen absorbed in 3 hours at 37° C. ...	·030	·035	·0514	·024	·035
Nitrites	minute trace	·000	·000	·0	·000

Bushey, cont.

Mixed water from the three wells of the Colne Valley Water Co., to show effect of softening.

A.—Natural water.

B.—Softened water.

Made and communicated by Dr. J. C. Thresh. September, 1900.

In parts per 100,000.

	A	B
Ca	12·5	2·6
Mg	·5	·4
Na	2·2	1·7
K	trace	trace
CO_3	15·6	1·6
SO_4	4·8	4·85
Cl	2·	2·
NO_3	2·35	2·5

Probable combinations:—

	A	B
Calcium carbonate	26·	2·6
Calcium sulphate	3·75	5·1
Magnesium sulphate ...	2·5	1·55
Sodium chloride	3·3	3·3
Sodium nitrate	3·25	3·5
Silica, etc.	1·2	·65
Total solids	40·	16·7
Permanent hardness ...	7°	7°
Temporary hardness ...	25°	3°
Total hardness	32°	10°
Free ammonia	·120	—
Albuminoid ammonia ...	·004	—

Dr. J. F. Beale made the following bacteriologic report in July, 1912, on a sample from tap off rising main at the Company's offices.

Number of organisms per cubic centimetre capable of growing upon nutrient gelatine at 20° C. in 3 days ... 64
Ditto upon agar at 37° C. in a day 0

Smallest quantity of water giving acid and gas in bile-salt glucose broth. Absent in 100 c.c.
Ditto, giving gas in bile-salt lactose broth. Absent in 100 c.c.
Ditto, containing *Bacillus coli communis*. Absent in 100 c.c.
Ditto, giving the reaction of *Bacillus enteritidis sporogenes*. Absent in 110 c.c.
Other bacteriologic examinations are described as very satisfactory.

Cheshunt.

According to G. Rennie's Report on the Supply of Water from the District of Bagshot, 1850, pp. 25, 26, the water of a well here had 18·3° of hardness, and a sample taken at 10 ft. below the top of the Chalk had the temperature of 53°.

Digswell.

Rectory New Well.

Made and communicated by Dr. J. C. Thresh. 1914.

In parts per 100,000.

Chlorine	4·
Nitric nitrogen	·3
Iron, chiefly in suspension	·1
Free ammonia	·005
Organic ammonia	·0058
Oxygen absorbed	·066

Hardness: Temporary, 3·5°; Permanent, 26·5°; Total, 30°.

Essendon.

Waterworks. *See* p. 211.

By Dr. T. Stevenson, March, 1899. From the Local Government Board.

Sample of March 3rd, clear, free from odour. With iron in solution equivalent to ·07 grain of carbonate per gallon.

Essendon, cont.

Sample of March 7th, free from odour. Pale yellow and slightly turbid. Its anaylsis, in grains per gallon, was as follows:—

Total solid matter	23·52
Loss on ignition	·56
Combined chlorine (equal to common salt ·72)	·56
Nitrogen as nitrates	·01
Nitrites	none
Ammonia	traces
Albuminoid or organic ammonia	·003
Carbonate of iron	·06
Oxygen required to oxidize the organic matter	·014

Hardness: Temporary, 18°; Permanent, 1·5°; Total, 19·5°.

Flamstead.

1. Markyate Waterworks of the Hemel Hempstead Rural District Council. *See* p. 212.

By Dr. J. C. Thresh, May, 1909. From the Local Government Board.

Turbidity slight. Fine sand and little chalk in deposit. Greyish tint. No odour.

In parts per 100,000.

Ca	11·
Mg	trace
N	trace
CO_3	15·5
SO_4	·25
Cl	1·3
NO_3	1·2

Probable combinations:—

Calcium-carbonate	25·8
Calcium-sulphate	·35
Calcium-chloride	2·
Calcium-nitrate	1·6
Etc.	·25
Total solid constituents dried at 180° C.	30·
Nitrites, lead, copper, zinc, iron	absent
Free ammonia	·0005
Organic ammonia	·0015
Oxygen absorbed at 98° in 3 hours	·004

Hardness: Permanent, 4°; Temporary, 18·5°; Total, 22·5°.

The water is of great organic purity and the only objectionable feature is its hardness.

2. A later analysis. By the Clinical Research Association. December, 1913. From the Local Government Board.

In parts per 100,000.

Combined chlorine (equivalent to NaCl 1·98)	1·2
Nitric nitrogen	·35
Nitrous nitrogen	nil
Ammoniacal nitrogen	·0003
Albuminoid nitrogen	·0017
Oxygen absorbed in 4 hours at 27° C. ...	·009
Lead or copper	nil

Of satisfactory organic purity.

Hadham, Much.

1. Nine Acres Plantation. *See* p. 217.

Made and communicated by Dr. J. C. Thresh. 25th February, 1904.

Hadham, cont.

In parts per 100,000.

		Probably combined as:—	
Ca	10·1	Calcium carbonate	24·65
Mg	·65	Calcium sulphate	·85
Na	1·2	Magnesium sulphate ...	1·4
CO_3	14·8	Magnesium chloride	1·35
SO_4	1·7	Sodium chloride	1·55
Cl	1·95	Sodium nitrate	2·15
NO_3	1·55	Silica, etc.	1·05
		Total solid constituents dried at 180° C. ...	33·

Hardness: Temporary, 22·5°; Permanent, 5°; Total, 27·5°.

Free ammonia	0
Organic ammonia	·01
Oxygen absorbed in 3 hours at 37° C. ...	·012
Nitrites	nil.

2. Private Well. No details.

Made and communicated by Dr. J. C. Thresh. February, 1903.

In parts per 100,000.

Chlorine	2·1
Equivalent to chlorides	3·5
Nitric nitrogen	·34
Equivalent to nitrates	2·04
Nitrites	nil.
Free ammonia	·000
Organic ammonia	·010
Oxygen absorbed in 3 hours at 37° C. ...	·012

Hardness: Temporary, 5·4°; Total, 24·9°.

Well wanting cleaning. Too much organic matter.

Harpenden.

1. Waterworks. *See* p. 218.

A.—By A. E. Ekins, March, 1911. } From the Local Government Board.
B.—By J. K. Colwell, July, 1913. }

Bright, clear, no smell.

Microscopic examination: *a.* Very satisfactory; *b.* showed the presence of a few mineral fragments.

In grains per gallon.

	A	B
Total solids	22·9	26·6
Chlorine	1·	1·1
Free ammonia	·0008	·0003
Albuminoid ammonia	·0006	·0004
Oxygen absorbed (4 hours at 80° F.)	—	·01
Nitrogen as nitrates	·27	·366
Nitrites	nil.	nil.
Total hardness	20°	20·5°
Permanent hardness	4°	3°

A water of great organic purity.

2. Water from Well in Chalk, 150 ft. deep.

Made (Nov. 10, 1908) and communicated by W. T. Burgess.

In parts per 100,000.

Total solid residue	34·82
Ammonia, free	0
Ammonia, albuminoid	·003
Nitrogen as nitrates	·326
Nitrogen as nitrites	0

Harpenden, cont.

	In parts per 100,000.
Oxygen absorbed in 4 hours at 80° F.	·025
Chlorine	1·45
Total lime (CaO)	15·5
Total carbonates, calculated as carbonate of lime	26·2

Hardness, total (by soap-test) 27·5°; permanent 3·6°; temporary 23·9°. Slightly turbid.

Hatfield.

Marquis of Salisbury. For public supply? *See* p. 219.

By Sir E. Frankland.

	In parts per 100,000.
Total solid matter	32·08
Organic carbon	·007
Organic nitrogen	·002
Ammonia	0
Nitrogen as nitrates and nitrites	·438
Total combined nitrogen	·44
Chlorine	1·4

Hardness: Temporary, 20·8°; Permanent, 4·3°; Total, 25·1°.

Hemel Hempstead.

Waterworks. *See* p. 220.

A.—Report of Waterworks Committee, 1910. Drawn from pump at Waterworks.

B.—Engineer's Annual Report for 1910–11.

Sample from Nos. 2 and 3 bores taken 5th April, 1911.

	In parts per 100,000.	
	A	B
Total solids, dried at 120° C.	32·8	32·3
Combined chlorine	1·07	1·1
Equivalent to NaCl	1·77	1·81
Nitric nitrogen (nitrates in A)	·3	·2
Nitrous nitrogen (nitrites in A)	nil.	nil.
Ammoniacal nitrogen (saline ammonia in A) ...	nil.	nil.
Albuminoid nitrogen (albuminoid ammonia in A)...	·0003	·0004
Oxygen absorbed in 4 hours at 27° C.	·0021	·003
Lead or copper	nil.	nil.
Hardness: Temporary	17·1°	17·3°
,, Permanent	1·8°	1·8°
,, Total	18·9°	19·1°

Bacteriologic examination. The same in both.

Average number of organisms producing visible colonies on gelatine-plates, incubated at 20·22° C. for 3 days. 4 per c.c.

Ditto on agar-plates, incubated at 37·5° C. for 2 days. Less than 1 per c.c.

B. coli, not found in 100 c.c.

Streptococci, not found in 30 c.c.

B. enteritidis sporogenes, not found in 100 c.c.

These results show the water to be of a high degree of organic and bacterial purity.

Hitchin.

In Ranger's Report to the General Board of Health on the supply of water, p. 16, [Lord] Playfair gives the hardness of the water from a well at Collins' Corner at the very high figure of 50½°.

Hitchin Waterworks. See *p.* 224. By REDWOOD and DE HAILES.

	Date of receipt of Samples.								
	Dec. 18th, 1905.			Jan. 5th, 1906.		Aug. 29th 1906.	Feb. 5th, 1907.	Jan., 1911.	Aug., 1913.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9
	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.	grs. per gal.
Total solid residues	24·	25·4	24·8	25·2	25·	25·6	27·4	26·8	25·6
Loss upon incineration	2·2	2·6	1·	1·4	1·	2·6	2·6	2·4	2·8
Chlorine in chlorides	1·49	1·49	1·49	1·49	1·49	1·24	1·49	1·49	1·49
Nitrogen as nitrates	·18	·22	·2	·23	·28	·2	·17	·18	·127
Nitrogen as nitrites	nil	nil	nil	nil	nil	nil	nil	no evidence.	no evidence.
Oxygen required (¼ hour, warm)	·02 parts per million.	·017 parts per million.	·017 parts per million.	·014 parts per million.	·014 parts per million.	·014 parts per million.	·028 parts per million.	·02 parts per million.	·014 parts per million.
Saline ammonia	·01	·01	·01	·01	·01	·01	·03	·02	none
Albuminoid ammonia	·03	·02	·04	·02	·02	·07	·03	·55	·025
Appearance in 2-ft. tube	pale bluish, very slight suspended matter.	pale bluish, very slight suspended matter.	pale bluish, very slight suspended matter.	pale bluish, very slight suspended matter.	pale bluish, slight suspended matter.	pale bluish, very slight suspended matter.	pale bluish, un-objection-able.	pale bluish, very slight trace of suspended matter.	
Taste and smell	nil	nil	nil	nil	nil	nil	un-objection-able.	un-objection-able.	

REMARKS:—No. 1, No. 2, No. 3.—Identical physically and chemically, and suitable for culinary and dietetic purposes.
No. 4 and No. 5.—Identical and fit for all culinary and dietetic purposes. Excellent waters.
No. 6.—Albuminoid higher than usual. Nevertheless excellent, and suitable for all culinary and dietetic purposes.
No. 7.—Excellent, suitable for all culinary and dietetic purposes.
The Samples are practically constant throughout.

Hoddesdon.

Private Well. No details.

Made and communicated by Dr. J. C. Thresh. April, 1900.

Clear. Almost colourless. A good water.

	In parts per 100,000.
Chlorine (equivalent to chlorides 5·)	3·
Nitric nitrogen (equivalent to nitrates ·96) ...	·16
Nitrites	nil.
Lead, copper, zinc, iron	nil.
Free ammonia	·050
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C. ...	·027
Hardness	17·1°

Knebworth.

Well for the Great Northern Railway Co. South of Roaring Meg Plantation, *see* p. 230.

From the Analyst's Department of the Co. By W. S. Young.

1. Sample taken from a depth of 25 ft., January, 1913. Opalescent, large reddish-brown sediment consisting chiefly of chalk and iron-oxide.

	In grains per gallon.
Total dissolved solids	54·4
Consisting of the following —	
Chalk	20·3
Salt	6·76
Calcium nitrate	11·3

The remainder being sulphates of lime and of magnesia.

Free ammonia	·007
Albuminoid ammonia	·0077
Chlorine as chlorides	4·1
Nitrogen as nitrates	1·93
Nitrogen as nitrites	trace

Microscopic examination.—After prolonged search among suspended matter no objectionable organisms were found.

Bacteriologic examination.—Number of organisms incubated on gelatine for 72 hours at 18°—22° C., 1,500 per cubic centimetre.

Number of organisms incubated on neutral red bile-agar for 72 hours at 37·5° C. (blood-heat). None.

This water is wholesome for drinking; but unsatisfactory for steam-raising, being very hard.

2. Sample taken from well after operations ceased, January, 1914.

Analysis for boiler-purposes.—

Total residue on evaporation, 46·83, composed as follows:—

Silica	·59
Alumina ... ... }	·18
Iron-oxide ... ... }	
Calcium-oxide	14·89
Magnesium-oxide	·66
Sodium oxide	3·81
Sulphuric anhydride	3·67
Carbonic anhydride	8·01
Nitric anhydride	6·55
Chlorine	3·85
Combined water	5·49

Knebworth, cont.

From the above results calculated in the conventional manner it would appear that the composition of solids is as follows:—

Calcium carbonate	18·18
Calcium sulphate	6·24
Calcium chloride	4·27
Magnesium chloride	1·46
Sodium nitrate	10·31
Silica	·59
Aluminium oxide ... ... } Ferric oxide ... ... }	·18

Analysis for drinking purposes.

Water opalescent and on standing deposited a small quantity of very finely divided sand and clay. No distinctive odour, either in the cold or when shaken in a closed vessel at 110° F.

Microscopic examination.—A careful search of the deposit failed to reveal the presence of any organism of objectionable character.

Total dissolved solids	46·83
Free ammonia	·0021
Albuminoid ammonia	·0056
Chlorine as chloride	3·85
Nitrogen as nitrates	1·66
Nitrogen as nitrites	minute quantity.

Bacteriologic examination.—Incubation at ordinary temperature (18° to 22° C.) on nutrient gelatine for 72 hours. No. of organisms per cubic centimetre, 5,000. Incubation at blood-heat, 37·5° C. on neutral red bile-agar for 72 hours. No. of organisms per cubic centimetre 3. No *Bacillus coli.*

Conclusions from the above analyses.—This water is of about the same character, as regards liability to form scale as the London water-supply; but is likely to form rather more and rather harder scale than that water. One of its constituents (not present in the London water) and here in unusually high proportion, sodium nitrate, is undesirable in water for locomotive-boilers, or for use in any kind of boiler composed of copper and steel. When such water becomes concentrated by evaporation in the boiler there will remain a strong solution of nitrates and chlorides, which, in contact with a copper-steel couple at the temperature of the boiler, are liable to electrolytic decomposition, with corrosion of the boiler-metals, particularly at the points of contact between the steel and copper.

For drinking purposes, the water cannot be described as wholesome, judged by this sample, because it contains organisms which have come originally from the human or animal intestine, though the quantity of pollution is only minute. But it is possible that this pollution is accidental and has arisen during the boring operations, which might happen in various ways.

Letchworth.

Garden City Waterworks, *see* p. 232.

1. By F. R. Stephens, February, 1904. From the Local Government Board. Colourless, odourless, clear.

	In grains per gallon.
Total solids at 100° C.	·24·
Total solids at 120° C.	23·
Total solids ignited	14·
Loss on ignition	9·
Iron and aluminium	0
Calcium	7·6
Magnesium	traces
Chlorine	·9
Sulphuric acid (SO_4)	·6
Carbonic acid combined (CO_3) ...	8·4
Alkalinity in terms of $CaCO_3$ ...	14·
Free ammonia	·005 } parts per
Albuminoid ammonia	·015 } million.

Letchworth, cont.

Hardness: Total, 20°; Permanent, 4·5°; Temporary, 15·5°.

This water is remarkably free from organic contamination.

Later analyses by Dr. S. RIDEAL. From the Local Government Board.

2. November, 1910. 3. February, 1911. 4. July 16th 1920. This latest analysis of a sample from a tap at the estate-office communicated by DR. RIDEAL.

	In parts per 100,000.		
	2	3	4
Total solids	34·16	33·28	34·96
Chlorine	1·25	1·2	1·2
Free ammonia	nil	nil	·0057
Albuminoid ammonia ...	·0027	·0005	·0016
Nitrates (as nitrogen) ...	·68	·712	·92
Nitrites	nil	nil	nil
Oxygen consumed	·058	·096	·0032
Alkalinity as $CaCO_3$ ...	—	22·5	23·4

In 3, Hardness (Clark's scale): Total, 15·5°; Permanent, 3·3°; Temporary, 12·2°. In 4, Temporary 20·16; Permanent 4·5.

In 2, Bacterial examination. *Coli* organisms absent from 85 c.c. of the water.

In 3, total organisms 5; rapidly liquifying 1; at 37·5°, less than 1; *Coli* organisms absent from 50 c.c. of the water, which is satisfactory and of excellent bacterial quality.

Mimms, North.

1. Trial-boring for the Barnet District Water Co., *see* p. 234.

Made and communicated by Dr. J. C. THRESH, December, 1913.

Trace of chalk. Faint yellow-green. No odour. Reaction neutral.

			In parts per 100,000.
		Probable combinations—	
Ca	10·6	Calcium carbonate	25·
Mg	·4	Calcium sulphate	2·05
Na	2·6	Magnesium sulphate ...	2·
CO_3	15·	Sodium sulphate	1·3
SO_4	3·9	Sodium chloride	3·5
Cl	2·1	Sodium nitrate	3·
NO_3	2·2	Silica, etc.	1·75
		Total solid constituents dried at 180° C. ...	38·6
		Free ammonia	·0018
		Organic ammonia	·0056
		Oxygen absorbed in 3 hours at 37° C.	·070
		Nitrites	nil

Hardness: Temporary, 21°; Permanent, 5·5°; Total, 26·5°.

2. Water from well, No particulars.

Made (April 1905) and communicated by W. T. BURGESS.

	In parts per 100,000.
Total solid residue	177·6
Ammonia, free	·20
Ammonia, albuminoid	·070
Nitrogen as nitrates	4·20
Nitrogen as nitrites	present.
Oxygen absorbed in 4 hours at 80° F.	·63
Chlorine	39·6

Hardness, total (by soap-test) over 62°.

Turbid, very much polluted.

Redbourn.

Prof. T. Graham, Dr. W. A. Miller, and Dr. A. W. Hoffmann, *Quart. Journ. Chem. Soc.*, 1852, vol. iv, pp. 405, 406.

	In grains per gallon.
Lime	10·3792
Magnesia	·258
Potassium	·34
Sodium	·334
Sulphuric acid	·3778
Chlorine	6·36
Carbonic acid	14·364
Silica	1·16
Nitric acid	·7
Carbonate of lime	17·94
Sulphate of lime	·11
Nitrate of lime	1·06
Carbonate of magnesia	·53
Chloride of sodium	·85
Chloride of potassium	·25
Sulphate of potassa	·58
Silica	1·16
Total	22·48
Residue obtained on evaporation ...	21·63
Free carbonic acid	6·24
Hardness	17·8°

Rickmansworth.

Batchworth.

Prof. T. Graham, Dr. W. A. Miller, and Dr. A. W. Hoffmann, *Quart. Journ. Chem. Soc.*, 1852, vol. iv, pp. 405-407.

	In grains per gallon.
Lime	9·033
Magnesia	·3587
Potassium	·4746
Sodium	·8246
Sulphuric acid	·9471
Chlorine	·6142
Carbonic acid	15·022
Silica	1·59
Nitric acid	·154
Carbonate of lime	16·13
Nitrate of lime	·23
Carbonate of magnesia	·75
Chloride of sodium	1·01
Sulphate of soda	1·31
Sulphate of potassa	·44
Carbonate of potassa	·48
Silica	1·59
Organic matter	1·26
Total	23·2
Residue obtained on evaporation ...	22·97
Free carbonic acid	7·6
Hardness	18·1°

When heated to boiling point hardness fell to 12°, by 5 minutes boiling to 5·6°, by 15 minutes to 4°, by 30 minutes to 2·8°, and by an hour's boiling to 2·6°.

St. Albans.

1. Waterworks (*see* p. 243). Drawn from the main on 14th October (older works).

By Sir E. Frankland, October, 1897.

Clear, bright, of a high degree of organic purity.

	In parts per 100,000.
Total solid matter	36·8
Organic carbon	·025
Organic nitrogen	·005
Ammonia	0
Nitrogen as nitrates and nitrites ...	·433
Total combined nitrogen	·438
Chlorine	1·6

Hardness: Temporary, 21°; Permanent, 5·9°; Total, 26·9°.

Bacteriologic examination, November, 1897. After 5 days' incubation the water contained only 4 microbes per cubic centimetre, any number not over 100 being satisfactory.

2. Waterworks, January, 1911. From the Local Government Board.

A.—Stone Cross Pumping Station.

B.—Holywell Pumping Station.

By A. E. Ekins.

	In grains per gallon. A	B
Total solids	25·3	23·8
Chlorine	1·2	·82
Free ammonia	·0007	·0014
Albuminoid ammonia	·0014	·0014
Nitric nitrogen	·46	·402
Oxygen absorbed in 15 minutes at 80° F.	·0025	·0042
Oxygen absorbed in 4 hours at 80° F.	·0093	·0085

Hardness: Total, 21° and 20·4°; Temporary, 19·25° and 19·2°; Permanent, 1·75° and 1·2°.

Appearance in 2-ft. tube colourless and clear in both.

Metals (lead, copper, zinc, iron) none in both.

Bacteriologic examination.—*Bacillus coli communis* absent in 1, 5, 10 cubic centimetres, in both.

The waters are of a high degree of organic and bacterial purity.

3. Waterworks. From Holywell Pumping Station.

By E. H. Fisher, December, 1913. From the Local Government Board.

	In parts per 100,000.
Free and saline ammonia	nil
Albuminoid ammonia	·004
Oxygen absorbed in 15 minutes at 80° F.	·0057
Oxygen absorbed in 4 hours at 80° F. ...	·0277
Nitric nitrogen	·48
Chlorine	1·4
Equivalent to sodium chloride	2·3
Total solid matter dried at 180° C. ...	35·
Hardness: Temporary 27·7°; Permanent, 3°.	

Appearance in two-foot tube, colourless and clear.

Minute trace of iron. No lead, copper, zinc.

A water of high organic purity.

4. Two analyses of Waterworks water. November, 1915.

Made and communicated by Dr. J. C. Thresh.

A.—From the Stone Cross well.

B.—From the Holywell well.

Clear and bright. Colour faintly green. No odour. Reaction neutral in both.

St. Albans, cont.

In parts per 100,000.

	A	B
Ca	12·4	12·
Mg	·25	·25
Na	2·75	2·1
CO_3	19·2	17·6
SO_4	1·4	1·6
Cl	2·2	2·
NO_3	1·8	2·1

Probable combinations—	A	B
Calcium carbonate	31·	29·3
Magnesium carbonate ...	·85	—
Calcium and magnesium sulphate	—	2·15
Sodium sulphate	2·05	3·3
Sodium chloride	3·6	—
Sodium nitrate	2·5	2·9
Silica, etc.	1·8	1·35
	nil	nil

Total solid constituents, dried at 180° C.	41·8	39·
Free ammonia	·003	·004
Organic ammonia	·002	·004
Oxygen absorbed in 3 hours at 37° C.	·018	·032
Nitrites	nil	nil

Hardness: Temporary, 27½° and 27°; Permanent, 4½° and 5°; Total, 32°, in both.

5. Herts Asylum, *see* p. 243. From the Local Government Board.

B.—Clearly is after softening (by Porter-Clark process).

In grains per gallon.

	A	B
Total solid matters (in B dried at 120° C.) ...	23·	12·6
Chlorine	1·1	1·08
Albuminoid ammonia	·00025	·0008
Nitrogen as nitrates, etc.	·171	·43
Hardness { Total	21°	6·6°
Hardness { Permanent	5·3°	—
Hardness { Temporary	15·7°	—

The water is of a high degree of organic and bacterial purity.

Sawbridgeworth.

Herts and Essex Water Works Co. *See* p. 246.

1. By Dr. J. C. Thresh, October, 1907. From the Local Government Board.

Clear, but a little dull. Yellow tint. No odour.

In parts per 100,000.

Total solid matter dried at 180° C.	44·2
Chlorine, 2·7. Equivalent to chlorides (60 p.c. Cl) ...	4·5
Nitric nitrogen, ·09. Equivalent to nitrates (17 p.c. N)...	·54
Nitrites	absent.
Lead, copper, zinc, iron	absent.
Free ammonia	·0188
Organic ammonia	·0032
Oxygen absorbed at 98° F. in 3 hours	·184

Hardness: Permanent, 6°; Temporary, 8°; Total, 14°.

Bacteriologic examination: Number of organisms per cubic centimetre capable of growing on alkaline nutrient jelly at 20° C. in 3 days, 10 only.

Smallest quantity of water in which growth occurred, with production of acid and gas in bile-salt glucose broth, not less than 20 c.c.

No *Bacillus coli* found.

Spores of *Bacillus enteritidis sporogenes*, absent in 500 c.c.

2. Sample taken from the rising main.

Made and communicated by Dr. J. C. Thresh. 1911.

Slight yellowish-white opalescence, due to a trace of ferruginous chalk. Faintly yellow. No odour. Reaction neutral.

Sawbridgeworth, cont.

In parts per 100,000.

		Probable combinations:—		
Ca	9·8	Calcium carbonate ...	...	24·5
Mg	1·2	Magnesium carbonate	...	4·2
? Na	3·05	Sodium sulphate ...	...	6·65
CO_3	17·8	Sodium chloride ...	...	4·6
SO_4	4·5	Sodium nitrate ...	...	·4
Cl	2·8	Silica, iron, etc. ...	...	3·75
NO_3	·3			
		Total solid constituents dried at 180° C. ...		44·1

Hardness: Temporary, 20°; Permanent, 10°; Total, 30°.

Free ammonia	·0146
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C. ...	·01
Nitrites	absent.

Standon.

Ware Gun Station, Bartram's Farm. *See* p. 248.

A.—Sample taken 19th December, 1916. By Lt.-Col. E. M. Copeman.

B.—Sample received 1st September, 1917, after deepening of bore. By Major A. G. R. Foulerton.

Both in parts per 100,000.

	A	B
Ammonia, free and saline	·0084	·005
Ammonia, albuminoid	·007	·0038
Nitrites as nitrogen	·0092	·0015
Nitrates as nitrogen	·2	·8
Oxygen absorbed (in 4 hours at 37° C.)	·04	·013
Chlorine	2·4	2·1
Total dissolved solids	40	39·
Volatile solids	4·	5·
Fixed, or non volatile solids	36·	34·
Poisonous metals	absent	absent
Hardness: Temporary	25°	24·75°
Permanent	3°	1°

A.—Water cloudy on arrival. On standing it gave a thick sediment, of clay and chalk, with clear water above. Reaction of the water neutral.

Bacteriologic examination.—One cubic centimetre contained, on an average, 5,925 bacteria capable of growth on gelatine-plates within 72 hours' incubation at a temperature of 22° C. A similar quantity of the water contained 80 bacteria capable of growth on agar-plates within 24 hours' incubation at a temperature of 37° C. *B. coli* was present in ·5 c.c. of the water, but not in 1 c.c.

The chemical and bacteriologic examinations show that the water is subject to heavy organic pollution. In its present condition it is unfit for drinking purposes.

B.—Sample taken after the bore-tube had been lengthened, to avoid a fissure in the Chalk which was suspected as a possible source of surface-pollution.

Water turbid, and contained much suspended matter. A heavy reddish-brown deposit, consisting mainly of iron-rust, was thrown down on standing, and the water remained slightly cloudy after standing for 48 hours. 91 per cent. of the deposit was ferric carbonate.

Bacteriologic examination.—One cubic centimetre contained, on an average, 51 bacteria capable of growth on gelatine-plates within 48 hours' incubation at a temperature of 22° C. This number increased considerably within 72 hours' incubation. An equal quantity of the water contained 10 bacteria capable of growth within 24 hours at a temperature of 37° C. *Bacilli* of the *colon* group were present in 50 c.c. of the water specially examined, but not in 10 c.c.

Standon, cont.

The following table seems to refer to both analyses :—

	No. of organisms growing at 22° C. (48 hours).	No. of organisms growing at 37° C. (24 hours).	Organisms of *colon* group.
1st October, 1916 ...	More than 8,000.	Uncountable.	Present in 1 c.c.
19th October, 1916 ...	5,925	80	Present in 1 c.c.
19th January, 1917...	2,792	630	Present in 10 c.c.
2nd May, 1917 ...	35	20 (48 hours, 37° C.)	Present in 50 c.c. Absent from 10.
1st August, 1917 ...	51	10	Present in 50 c.c. Absent from 10.

A comparison of the result with the results of previous examinations shows distinct improvement in the bacteriologic quality of the water.

Conclusions.—The presence of nitrites is probably due to partial reduction of the nitrates by iron-salts. From the chemical point of view, and apart from the rust present, the water is of satisfactory quality. From the bacteriologic point of view the water is fit for drinking, but still has a rather high bacterial content for a deep well in the Chalk ; but this may be due partly to recent operations on the well, and it may be expected that the quality of the water will improve in this respect.

In its present condition the water is unsuitable for use. It is recommended that the rust should be got rid of by continuous pumping for several hours every day, until the water gets clear.

Stevenage.

1. From deep boring, for the Great Northern Railway Co., south of Langley Siding. *See* p. 249.

From the Analyst's Department of the Co. By W. G. Young.

Two analyses, 25th May and 5th June, 1908, gave identical results.

Clear, bright and well aerated. In the first after standing some time there was a slight white precipitate, which proved to be chalk.

	In grains per gallon.
Total dissolved solids	24·3
Consisting of the following :—	
Calcium carbonate	18·6
Magnesium carbonate...	3·3
Magnesium sulphate	·72
Sodium chloride	1·65
Substances unestimated	·03

A good boiler-water. Peculiarly adapted for softening.

2. Waterworks. *See* p. 250. 1903 ? From the Local Government Board. No odour. Colourless and clear when viewed in bulk.

	In grains per gallon.
Total solid matter	20·44
Loss on ignition	1·68
Combined chlorine (equal common salt 1·6) ...	·97
Nitrogen as nitrates	·2
Nitrites	none.
Ammonia	traces.
Albuminoid or organic ammonia	·003
Oxygen required to oxidise the organic matter	·004
Hardness : Temporary, 14·7° ; Permanent, none.	

Number of bacteria per one cubic centimetre, 3.

An excellent water. Neither the chemical analysis nor the bacteriologic examination show any organic pollution.

Ware.

1. A new well (1899). Musley Lane ?
Made and communicated by Dr. J. C. Thresh. May, 1899.

	In parts per 100,000.
Chlorine (equivalent to chlorides 2·7)	1·6
Nitric nitrogen (equivalent to nitrates 2·9)	·49
Nitrites	nil
Free Ammonia	·000
Organic ammonia	·004
Oxygen absorbed in 3 hours at 37° C.	·0414

Hardness: Temporary, 12·1° ; Total, 18·7°.

2. Musley Hill Waterworks. 3. Musley Lane Waterworks, *see* pp. 259, 260.
Both September, 1910.
By A. E. Ekins. From Local Government Board.

	In grains per gallon.	
	2	3
Total solids	[illegible]	27·
Chlorine	1·5	1·5
Free ammonia	·0038	·0034
Albuminoid ammonia	·0016	·0015
Nitrogen as nitrates, etc. ...	·148	·149
Oxygen absorbed in 15 minutes at 180° F.	·0429	·0421
Oxygen absorbed in 4 hours at 180° F.	·105	·106
Appearance on ignition ...	white	white

Microscopic examination.—2, Found granulated particles. 3, Very satisfactory.

2. Of good quality; but a public supply should be free from sediment. Perhaps a bore-pipe may be defective.

3. Clear and bright and of very good quality.

4. Musley Hill Waterworks. 5. Musley Lane Waterworks.
Both November, 1915.
Communicated by H. F. Hill, Surveyor.

	In grains per gallon.	
	4	5
Total dissolved matter	28·28	30·52
Loss on incineration of residue ...	2·52	2·52
Chlorine in chlorides	1·5	1·7
Equal to chloride of sodium ...	2·47	2·8
Nitrogen in nitrates	·25	·52
Equal to nitric acid	·96	2·01
Free (actual or saline) ammonia ...	·001	·001
Albuminoid (organic) ammonia ...	·001	·001
Phosphoric acid	traces	traces

Watford.

1. Leavesden. St. Pancras Schools, *see* p. 262.

Made and communicated by Dr. J. C. Thresh. 1904.
No turbidity. Colour bright.

			In parts per 100,000.
Ca	11·3	Probable combinations—	
Mg	·2	Calcium carbonate	25·7
CO_3	15·4	Calcium sulphate	1·15
SO_4	·8	Calcium chloride	1·8
Cl	1·4	Magnesium chloride	·35
NO_3	3·8	Magnesium nitrate	·6
		Potassium and sodium nitrates	4·7
		Silica, etc.	2·4
		Total solid constituents dried at 180° C. ...	36·7

Watford, cont.

Hardness: Total	27°
Free ammonia	·0004
Organic ammonia	·0004
Oxygen absorbed in 3 hours at 37° C.	nil
Nitrites	nil

2. Watford Railway Station, *see* p. 263.

By R. Phillips, *Proc. Inst., C.E.*, 1849, vol. viii, p. 172, and 1850, vol. ix, p. 177.

General Board of Health. Report on the Supply of Water to the Metropolis. Appendix ii, table opp. p. 93, 1850.

In grains per gallon.

Carbonate of lime	19·54	Total 23·7
Sulphate of lime	·94	
Muriate of soda	1·9	
Carbonaceous matter	1·32	

3. Public supply.

According to the Report of the Medical Officer of Health for 1898, there was an indication of the water not being so good as formerly.

4. Public Supply. No. 1 well, *see* p. 264.

Made and communicated by Dr. J. C. Thresh. 1899.

Clear and colourless.

In parts per 100,000.

Ca	12·5	Probable combinations—	
Mg	·3	Calcium carbonate	25·3
Na	·9	Calcium sulphate	3·4
CO_3	15·2	Calcium nitrate	5·8
SO_4	2·4	Magnesium chloride	1·2
Cl	2·3	Sodium chloride	2·3
NO_3	4·4	Silica, aluminium oxide, etc. ...	1·5
		Total solid constituents dried at 180° C. ...	39·5

Hardness: Temporary, 22°; Permanent, 8°; Total, 30°.	
Free ammonia	·001
Organic ammonia	·006
Oxygen absorbed in 3 hours at 37° C.	·027
Nitrites	nil

5. Sample from No. 1 well, 9th January, 1911.

Clear and bright. A few particles of iron-scale.
Colour faintly green. No odour. Reaction neutral.

6. Sample from tap off pumping main, December, 1913.

Clear and bright. No deposit. Very faint green tint. No odour. Reaction neutral.

Both by Dr. J. C. Thresh and Dr. J. F. Beale. From Local Government Board (5 in Water Works Directory, 1911).

In parts per 100,000.

	5	6
Total solid matter, dried at 180° C.	42·2	46·5
Chlorine	2·2	2·6
Equivalent to chlorides (60 p.c. Cl) ...	3·7	4·3
Nitric nitrogen	·83	·98
Equivalent to nitrates (17 p.c. N)	4·95	5·85
Nitrites	absent	absent
Lead, copper, zinc, iron	faint trace of iron.	very minute trace of iron.

Watford, cont.

	In parts per 100,000. 5	6
Free ammonia	·0016	·0008
Organic ammonia	·002	·0022
Oxygen absorbed at 36·6° (in 6 at 37° C.) in 3 hours	·014	·01
Hardness { Permanent, in 5, 6·3°, in 6, 5° Temporary, in 5, 14·7° in 6, 16° Total, in 5, 21°		
Number of organisms per cubic centimetre capable of growing upon nutrient gelatine at 20° C. in 3 days	32	42
Number of organisms per cubic centimetre capable of growing upon agar at 37 C°. in one day	18	8
Smallest quantity of water giving acid and gas in bile-salt glucose broth	Absent in 36 c.c.	60 cc.
Smallest quantity of water giving gas in bile-salt lactose broth	Absent in 36 c.c.	—100 c.c.
Smallest quantity of water containing *Bacillus coli communis*	Absent in 36 c.c.	—100 c.c.
Smallest quantity of water giving the reaction of *Bacillus enteritidis sporogenes*	Absent in 110 c.c.	—150 c.c.

In both the water is of excellent quality both chemically and bacteriologically, and is well adapted for public supply. *See also* table, p. 332.

Welwyn.

1. Church Fields Cottages, Lower Green. ? Hertford Rural District Council, *see* p. 265.

Made and communicated by Dr. J. C. Thresh. November, 1914.

Faintly opalescent. Yellow-green tint. No odour. Reaction neutral.

In parts per 100,000.

		Probable combinations—	
Ca	10·6	Calcium carbonate	26·3
Mg	·06	Calcium sulphate	·35
Na	2·5	Magnesium sulphate	·3
CO_3	15·8	Sodium chloride	3·
SO_4	·6	Sodium nitrate	4·8
Cl	1·8	Silica and trace of iron ...	·85
NO_3	3·5		

Total solid constituents, dried at 180° C.	35·6
Free ammonia	·0008
Organic ammonia	·0096
Oxygen absorbed in 3 hours at 180° C.	·0700
Nitrites	nil

Hardness: Temporary, 22·5°; Permanent, 3·5°; Total, 26°.

2. Made (April 1905) and communicated by W. T. Burgess.

	In parts per 100,000.
Total solid residue	29·56
Organic carbon	·114
Organic nitrogen	·010
Ammonia, free	0
Ammonia, albuminoid	·005
Nitrogen as nitrates	1·579
Nitrogen as nitrites	0
Total combined nitrogen	1·589
Oxygen absorbed in 4 hours at 80° F.	·024
Chlorine	1·85

Hardness, total (by soap-test) 17·7°; permanent 10·2°; temporary 7·5°.

Analyses of Water from Deep Wells in Chalk, in Hertfordshire. Sixth Report River Pollution Commission, 1874, pp. 100, 101.
In parts per 100,000.

	Depth of Well in feet.	Temp. Centi-grade.	Total solid impurity.	Organic Carbon	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen	Chlorine.	Hardness. Temporary	Hardness. Permanent.	Hardness. Total.	Remarks.
Bushey Station, November, 1870...	249	10°	36·08	·034	·018	0	·174	·192	1·9	19·7	6·	25·7	Clear and palatable.
Bushey Meadows, Borehole, November, 1870	—	10·6°	33·88	·027	·006	·006	·314	·325 (?·326)	1·35	23·8	3·8	27·6	„ „
Ditto, March, 1873	—	—	33·16	·071	·026	·029	·343	·393 (?·395)	1·4	23·2	4·3	27·5	„ „
Bushey, well near, Mr. Marjoribanks, March, 1873	—	—	38·2	·038	·017	·003	·605	·624 (?·625)	1·8	21·9	6·9	28·8	Turbid. Palatable.
Hertford, Waterworks, January, 1873	—	9·4°	37·06	·026	·008	0	·497	·505	1·9	21·4	4·6	26·	Clear and palatable.
Kimpton, Blackmore End, April, 1874	175	10·3°	38·32	·029	·007	0	·303	·31	3·	27·	4·	31·	„ „
Ditto, Farm at, April, 1874 ...	150	10·8°	54·6	·035	·03	0	·89	·92	6·3	31·7	7·4	39·1	Slightly turbid. Palatable
Rickmansworth, by Moor Park [Batchworth], February, 1871...	—	—	36·12	·033	·014	0	trace.	·914	1·68	27·3	4·6	31·9	Clear and palatable.
Watford, Waterworks, November, 1870	100	11·2°	38·2	·03	·015	·001	·752	·768	1·6	24·2	4·6	28·8	„ „
Ditto, March, 1873	100	—	37·26	·042	·011	·001	·774	·786	1·8	22·2	6·	28·2	„ „
Watford, Sedgwick's Brewery, November, 1873	180	11·1°	35·16	0	0	0	·635	·635	1·5	21·9	6·	27·9	„ „

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With the exception of the County six-inch maps the titles in the following list have the prefix **B** for such as refer to Buckinghamshire only, and the prefix **H** for such as refer to Hertfordshire only, those referring to both counties having both letters. It will be seen that **H** is by far the most common, Hertfordshire Waters having a fairly large literature.

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Maps.

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B. H.—15 (new series). SE. corner. 1910.
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ADDENDA.

A good amount of information has come to hand whilst this Memoir was passing through the press, and in order not to disturb the page-arrangement this is now printed at the end. It consists chiefly of two important entries, which add much to the interest of the work, and one of them gives details of great value in regard to deep-seated geology.

Buckingham.

G. B. Chilvers, Borough Engineer, has given a general account of the Waterworks, in *Water*, 1920, vol. xxii, No. 259, p. 226, from which the following is taken.

The original supply, in 1889, was taken by gravity from wells at Akeley (*see* p. 120). This failed after a time and borings were made at Maid's Moreton (*see* pp. 144–146). The original scheme still supplies a small quantity of water, varying according to the rainfall. The total quantity used daily is about 90,000 gallons. The night-flow is taken from two wells at Gawcott (*see* p. 124).

Iver Heath, 1920.

A letter from C. L. Kaye says that a boring of 5½ in. diameter made for the Heatherden Estate reached the Chalk and went about 100 ft. in it; but at a depth of 395 ft. no water was found.

Cheshunt.

? Cheshunt Common or Flamstead End. High View Nurseries. 1920. *See* p. 200.

A newer well.

Made and communicated by Messrs. Richards.

Lined with 181 ft. of tubes of a foot diameter, from 7 ft. down.

		Thickness. Ft.	Depth. Ft.
Sump-pit		—	8
[London Clay] ...	Brown clay and claystone ...	14	22
	Brown clay...	8	30
	Brown clay and claystones ...	84	114
	Blue sandy clay	17	131
[Reading Beds, chiefly]	Sand	12	143
	Sand and black gravel	9	152
	Hard sand and shells	24	176
	Black stones and sand	3	179

[Upper] Chalk and flints, to 284 ft. down, May, 1920; and water-level 241 ft. down.

The occurrence of shells in the sand of the Reading Beds is unusual.

It is difficult to mark the base of the London Clay; but the following notes on specimens by G. Barrow help, and tend to show that it is lower down than might be expected from the mere reading of the above section.

8 ft. Yellowish clay.
34 ,, Brown-grey clay.
90 ,, Unweathered London Clay, grey-brown, dry.
114 & 125 ft. the same.
131 ft. Grey sand, rather claycy, with fragments of shells.
135 ,, Brown-grey sand left on washing.
140 ,, Grey sand, Broken shell. } Basement-bed.
144 ,, Pebbles, sand, shells, fish-tooth. }
151 ,, Very pale grey sand and carbonaceous matter.
156 ,, Faintly greenish-grey sand.
158 ,, Yellow-sandy clay and marl.
159 ,, Very pale sand, with race and shells.
171 ,, Faintly greenish-grey sand, with pebble.
178 ,, Green clayey sand.

Letchworth.

Additional information as to the Waterworks (*see* p. 232) from A. W. E. Bullmore, the Engineer.

The following table shows the growth of the supply, following the number of new buildings. The supply from 1905–1912 has been published in C. B. Purdom's "The Garden City," 1913; but all the other figures are new :—

Year ending 30th September.	New buildings (total).	Supply, in million gallons.
1904	36	
1905	280	10
1906	507	16
1907	970	22
1908	1,104	34
1909	1,206	41
1910	1,334	53
1911	1,564	70
1912	1,761	85
1913	1,862	93
1914	1,967	94
1915	2,168	99
1916	2,296	136
1917	2,296	161
1918	2,298	186
1919	2,342	177

He gives the water-level as 100 ft. down and the tested yield from the four borings as a million gallons a day.

The following, the latest analysis, by Dr. S. Rideal, is of a sample taken 16th July, 1920 :—

	In parts per 100,000.
Total solids	34·96
Chlorine	1·2
Free ammonia	·0007
Albuminoid ammonia	·0016
Nitrates (as Nitrogen)	·92
Nitrites	nil
Oxygen consumed	·0032
Alkalinity	23·4

Hardness : Temporary, 20·16 ; Permanent, 4·5.

Bacterial examination.

Organisms per c.c. at 20° C. 5.
" " 20° C. R.L. 1.
" " 37·5° C. less than 1.

Coli organisms absent from 50 c.c. of the water.

Clear, colourless, odourless. Quite satisfactory and of excellent bacterial quality.

Welwyn Garden City.

Ordnance Map, 239 new ser. (Herts. 28, N.E. and S.E.). Geologic Map 46, S.E.

Our Second Garden City, like the first, at Letchworth, is in Hertfordshire.

The estate of this new establishment is nearly four square miles in area, between the rivers Lea and Mimram, and spreads into four parishes (Ayot St. Peter, Digswell, Hatfield and Welwyn). As, however, it is likely to exceed any of these in population, and perhaps all of them together, it is best to treat of its water-supply as a whole, regardless of the particular parish that may be concerned in any site.

The question of water-supply of course had to be considered at an early stage of the work, and it was not a case of providing simply for the supply of the population to be lodged, but in the first place it was essential to consider the needs of the workmen to be employed, and of the work to be done before any large population could be gathered in.

I had the pleasure of being consulted on the subject, and, in association with J. D. Haworth, the consulting engineer, visited the district at various times, for this and other purposes.

Welwyn Garden City, cont.

Of course existing supplies had to be seen to, for various temporary purposes that could not wait for the establishment of the large pumping station that would be needed for the permanent supply, and these will be noticed first, with analyses of the water directly following the note of the wells.

Several wells in the neighbourhood have already been noticed (*see* pp. 177, 211, 251, 265), but none of these are on the estate.

Handside.

On the western side of the road to Lower Handside, about 110 yards southward from the Luton Railway. Used for local supply, and for the neighbouring saw-mills, during the war and for some time after.

About 320 ft. above Ordnance Datum.

Old well of 3 ft. diameter ; 109 ft. deep, into Chalk.

A test by baling, made by Messrs. Le Grand and Sutcliff in June, 1920, showed that in lifting 120 gallons an hour for five hours the water-level, which was about 106 ft. down, was lowered a little more than 4 inches an hour, and they concluded that not more than 200 gallons an hour, if as much, could be got.

This quantity being very far from what was wanted, though it had served for the former supply, to the saw-mills, etc., it was decided to bore, and a boring was made to the depth of 164 ft. (with a tube of 8 in. diameter to 10 ft. below the bottom of the well), throughout in fairly hard chalk. The water stood at the original level.

A test was made of eight hours' continuous pumping, resulting in a yield of about 3,600 gallons an hour, with a lowering of only 7 in. in the water-level. A three days' test gave a yield of 3,540 gallons an hour.

Since 15th July, 1920, a supply of 10,000 to 12,000 gallons a day has been got (presumably all that was wanted), lowering the water level only two or three feet. This is a successful instance of a large increase of yield being got from deepening by boring.

An analysis of the water of this well (then described as the Saw Mills Well), dated 16th January, 1920, before the boring was made, by Dr. J. C. Thresh and Dr. J. F. Beale, was as follows :—

Sample taken from pump-main.
The water is a typical Chalk-water of excellent quality.
Naturally hard (about 20°). Contained a trace of chalk.
Faint green. No odour. Neutral Reaction.

	? In parts per 100,000.
Total solid matter, dried at 180° C. ...	38·
Chlorine (equivalent to chlorides 3·7) ...	2·2
Nitric nitrogen (equivalent to nitrates 2·4)...	·4
Nitrites	nil
Trace of iron	—
Free ammonia	·0028
Organic ammonia	·0026
Oxygen absorbed at 37° C. in 3 hours ...	·028

Number of organisms per c.c. capable of growing upon nutrient gelatine at 20° C. in 3 days, 460. Ditto upon agar at 37° C. in a day, 2.

Smallest quantity of water giving acid and gas in bile-salt glucose broth, under 100 c.c. Ditto giving gas in bile-salt lactose broth, 100 c.c. Ditto containing the *Bacillus coli communis*, 100 c.c. Ditto giving the reaction of the *Bacillus enteriditis sporogenes*, under 100 c.c.

The waters of two other wells on the estate have also been analysed by Drs. Thresh and Beale, and these may be taken together.

A.—Sand Pit Cottages. North-west of Hatfield Hyde. Well said to be sunk through gravel into chalk. Depth unknown.

Contained a few specks of vegetable débris.

B.—Digswell Lodge Farm. West of the Great Northern Railway, a little northward of the junctions with the two branches. Over 60 ft. deep, in the farmyard.

Contained specks of vegetable débris.
Both faint green. No odour.
Reaction. Neutral.

Welwyn Garden City, cont.

Chemical analysis—	In parts per 100,000— A	B
Total solid matter dried at 180° C. ...	83·	37·
Chlorine	7·6	2·
Equivalent to Chlorides	12·7	2·9
Nitric nitrogen	1·6	·36
Equivalent to nitrates	9·6	2·15
Nitrites	nil	nil
Lead, copper, zinc, iron	trace of iron.	trace of iron and zinc.
Free ammonia	·0084	·0088
Organic ammonia	·0056	·009
Oxygen absorbed at 37° C. in 3 hours	·045	·07
Hardness, total	44°	28°
Bacteriologic Examination—		
Number of organisms per c.c. capable of growing upon nutrient gelatine at 20° C. in 3 days	4450	9240
Ditto, upon agar at 37° C. in a day	12	16
Smallest quantity of water giving acid and gas in bile-salt glucose broth	over 100 c.c.	10 c.c.
Ditto, giving gas in bile-salt lactose broth	under 100 c.c.	40 c.c.
Ditto. containing the *Bacillus coli communis*	100 c.c.	40 c.c.
Ditto. giving the reaction of the *Bacillus enteriditis sporogenes* ...	under 100 c.c.	under 100 c.c.

A.—Not a Chalk-water: probably derived from Boulder Clay. Hardness excessive. Affected by manured land and possibly by drainage. A very unsatisfactory water, not suitable for domestic purposes.

B.—This water is slightly polluted; but is of the same character as that from the sawmills well (Handside). The pollution is more like surface-water than infiltration of manurial matter. In its present condition it cannot be certified as pure or wholesome.

The following are the depths of some other wells on the estate. Brickhill Farm (? Brickwell, on eastern side of high road, opposite Brocket Park), between 120 and 130 ft.; deepened in 1911. Dagnell Green, about a quarter mile north-westward of Lower Handside Farm, 107½ ft. Lower Handside Farm, on the eastern side of the road, less than half a mile southward of Handside (marked Upper Handside on the one-inch map), 92 ft. Upper Handside Farm, on the western side of the same road a little further southward, 98 ft.

When work is more advanced and more houses have been built the supply will come from the new waterworks, which may perhaps also supply places outside the border of the estate, as has been the case at Letchworth. This will probably be a useful function of most schemes of the sort, which will get over the difficulty of giving a water-supply to sundry villages that can hardly act alone.

Waterworks.

The site is in field 39 of the 25 in. Ordnance Map (Herts. 28, 7) in the parish of Welwyn, close to its boundary with Digswell. By the southern edge of the marsh, about 550 yards north-north-eastward of Digswell Church. 1920.

Made and communicated by Messrs. Le Grand and Sutcliff, and from J. D. Haworth.

207·4 ft. above Ordnance Datum.

A boring of a foot diameter to the depth of 50 ft. when it became impossible to drive the tubes into the gravel without damaging them. A tube of 8 in. diameter, with a cutting edge at the bottom, was then inserted and driven through the gravel and into the Chalk to the depth of 78 ft. (shutting out the gravel-water), below which the boring is unlined.

Welwyn Garden City, cont.

Directly gravel was touched (May or June, 1920), at 50 ft., water rose in the borehole, which was dry before, to within 9 ft. from the surface (ultimately 9½). It rose to 7½ ft. when the Chalk was reached.

		Thickness. Ft.	Depth. Ft.
[? River Drift] ...	Soil, sand and gravel	9	—
	Stiff brown boulder-clay	1½	10½
	Blue clay	10½	21
	Grey sandy silt	22½	43½
[Glacial Drift] ...	Hard blue clay	6½	50
	Gravel, some fine, with some large flints and some lumps of boulder-clay	12	62
	Chalk, soft	63	125
	Chalk, harder	76	201

Another note says that hard chalk was met with at the depth of about 170 ft.

When at the depth of 110 ft. pumping tests were made, the water-level being 7½ ft. down, with the following results.

	Pumping Hours.	Average Rate per Minute. Gallons.	Rate per hour. Gallons.	Water-level reduced. Feet.	Returned to level after pumping in Minutes.
First day ...	9½	315	18,900	11	1
Second day	8	385	23,100	15½	1½
Third day ...	8	330	19,800	12½	1½

Fourth day Practically repetition of third and results almost identical.

At one period the pump was run at a speed to deliver 400 gallons a minute for an hour; but this failed to reduce the water-level below 20½ ft. down.

Mr. Haworth concludes from this that there is an inflow of water to the borehole at the rate of 300 to 400 gallons a minute, within a depth of 21 ft., indicating that there will be an ample supply for from 40,000 to 50,000 people.

The quantities got during the tests point to a supply for 15,000 to 20,000 people, at 20 gallons a head, from an 8-in. borehole; so that much more can be expected from more extended work.

Some Deep Borings lately made, to the Lower Greensand.

By W. Whitaker and J. Pringle.

In that part of the London Basin not very far westward of London three deep borings have been made through the Tertiary beds, the Chalk, etc., which have been successful in finding the Lower Greensand and in getting water from it. The first is at Winkfield, in Berkshire, made in 1893, the second at Ottershaw Park, near Chertsey, in Surrey, made in 1910, and the third at Slough (*see* p. 158), made in 1909; and all of these have been described.

We are now able to add accounts of four others, which, however, do not pass through any Tertiary beds, with a very slight exception in one case, but, after passing through surface-deposits, enter at once into the Chalk.

Although one of these is outside our particular area, yet, as it is but a little way over the border of Buckinghamshire and naturally goes with the others, we have included it.

One of us (J. P.) having examined specimens from all these borings has of course been the chief contributor to the following descriptions.

Maidenhead.

Waterworks.

Made and communicated by A. TIMMINS.

		Thickness. Ft.	Depth. Ft.
Upper Chalk.	Bored by percussion to 130 ft. Continued, with fragments of *Inoceramus*	—	250
[Chalk Rock] ...	Nodular chalk with green grains (Chalk Rock)	4	254
	Chalk	6	260
	Nodular chalk	4	264
[Middle and Lower Chalk.]	Chalk without flints, except for a few at 273 ft. Irregular marly partings. At about 383 ft. a few inches of green and thick chalk, with marcasite-nodules. A markedly phosphatic film 2 to 3 in. thick	119	383
	Chalk	167	550
	Passage-beds from Chalk to beds below	130	680
Upper Greensand ...	Greensand with phosphatic nodules	3½	683½
[Gault, 256½ ft.] ...	Gault, very sandy clay	50½	734
	Gault, containing greensand ...	2	736
	Gault clay, pale at top; gets darker	204	940
[Lower Greensand, ?83 ft.].	Sandy yellowish green sand at 945 ft. up [?down] to 1,018 ft. coarse sandy material broken up	—	1,018
	Yellowish, sandy. Full of larger pebbles	5	1,023
Oxford Clay.	Grey clay, dries very hard; pyrites ...	2½	1,025½

The base of the Upper Chalk is taken at 264 ft. from the surface, and the thickness of the remaining part of the formation is nearly the same as that of the combined thickness of the Middle and Lower Chalk at Slough (*see* p. 158).

The clay described as Oxford Clay by the drillers is likely to be of Lower Greensand age. It is comparable with a part of the 12 ft. band of clay passed through in the Slough Motor Transport Depot boring, as suggested by Mr. BOOTH, but there is no palæontological evidence to confirm this correlation.

Great Marlow.

Waterworks (*see* p. 147). New Boring, 1920.

Bored and communicated by Messrs. ISLER and Co.

Lined with 33 ft. of 10 in. tubes (from 3 ft. down), 635 ft. of 6-in. tubes (from a foot down), and 123 ft. of 5-in. tubes (from 591 ft. down).

		Thickness. Ft. In.	Depth. Ft. In.
[Chalk Rock]	Loose chalk	6 0	6 0
	Chalk rock	3 6	9 6
[Middle and Lower Chalk, 446 ft.]	Chalk	285 0	294 6
	Hard white chalk	40 6	335 0
	Grey chalk	85 0	420 0
	Grey clay	36 0	456 0
[Upper Greensand, 14 ft.]	Greensand and clay	9 0	465 0
	Grey clay	2 0	467 0
	Grey sandy stone	3 0	470 0
Gault, mainly dark grey clay		242 0	712 0
[Lower Greensand]	Coarse yellow sandstone. Water	4 0	716 0
	Brownish-yellow sand, well rounded quartz grains	—	—

This boring commenced in Chalk Rock at a ground-level of 171 ft. above Ordnance Datum. Water (somewhat salt) was obtained at the depth of 717 ft. after reaching the Lower Greensand, and the yield at ground-level is 1,200 gallons an hour with a pressure of 10 lbs.

Wooburn, *see* p. 169.

Wooburn Green. Messrs. Wiggins, Teape and Co., Ltd. Paper Mill. 1920.

Bored and communicated by Messrs. Isler and Co.

Lined with 31 ft of 11½-in. tubes, 694 ft. 8 in. of 8-in. tubes (from 1½ ft. down), 131 ft. of 6-in. tubes (from 606 ft down), and 49 ft. of 5-in. tubes (from 752 ft. down).

		Thickness. Ft.	Depth. Ft.
Mould		4	4
[River gravel]	Ballast	13	17
[Upper, Middle and Lower Chalk]	Chalk	288	305
	Rock Chalk	104	409
	Grey rock	119	528
Blue Gault		246½	774½
Lower Greensand		2½	777

This boring probably enters the lower portion of the Upper Chalk after passing through the gravel. Apparently the thickness of Middle and Lower Chalk is similar to that recorded at Marlow (*see* p. 148). Water was obtained from the Lower Greensand, and overflows at the rate of about 20,000 gallons an hour. The site level is estimated to be about 130 ft above Ordnance Datum.

Slough Motor Transport Depôt.

Ordnance Map 255, new ser. (Bucks. 53, S.W.), Geological Map 7.

The water supply from the gravels at these works is noticed on pp. 159, 160. For an account of the constructional details of this borehole *see Proc. Geol. Assoc.*, vol. xxxi, pt. 3, 1920, pp. 135–139. In this account W. H. Booth says "it was hoped to get water from the Chalk, but this stratum was practically dry for the purposes of the depot, that is, it yielded but little water as compared with the large demand."

"The Chalk having failed, it was decided to carry on to the Lower Greensand," which was done with the result now given. The borehole is 610 yards S. by W. of Biddles Farm at a spot 104. ft above Ordnance Datum. The details of the section, set forth below, are based on a personal examination of the cores, and on notes supplied by W. H. Booth who had charge of the work, and to whom we are indebted for much assistance.

		Thickness. Ft. In.	Depth. Ft. In.
[River Drift]	Earth	5 0	—
	Gravel	18 6	23 6
[Reading Beds]	Red mottled clay	5 6	29 0
[Upper Chalk, 276 ft.]	Chalk and flints	207 0	—
	Chalk	24 0	—
	Grey chalk	20 0	—
	Dark grey chalk	15 0	295 0
	Hard whitish-grey nodular chalk. At 295 ft. the nodules are green coated; chalk traversed by numerous irregular slickensided joints. Chalk Rock. about	10 0	305 0
	White chalk with a few thin dark marly films	67 0	—
	Hard greyish-white chalk breaking with a splintery fracture...	18 0	—
[Middle Chalk, 225 ft.]	Greyish-white chalk, nodular in places. Numerous fragments of *Inoceramus*	131 0	—
	Hard splintery chalk, rings under hammer; near middle the chalk is thin-bedded and shows irregular surfaces streaked with greenish marly chalk. Melbourn Rock	9 0	530 0

Slough Motor Transport Depôt, cont.

		Thickness. Ft.	In.	Depth. Ft.	In.
[Lower Chalk, 192 ft.]	Laminated grey green-tinged marly chalk with fish remains: Belemnitella Marl?	0	6	—	
	Greyish white chalk with a 6-inch marly parting at 588 ft. *Holaster* fragments	85	6	—	
	Greyish-white marly chalk ...	9	0	—	
	Grey sandy chalk with small specks of glauconite near base ...	11	6	—	
	Dark grey marly chalk with several hard pale sandy bands, 2 to 6 in thick. Numerous sponge remains at 666 ft. *Schloenbachia varians* (J. Sow.) and *Inoceramus crippsi*. Mant. common	43	6	—	
	Pale grey sandy marl with minute grains of glauconite	22	0	—	
	Blocky grey marly chalk, distinctly green in hue when fresh, but becomes quickly pale in colour on exposure. Base slightly sandy with minute grains of glauconite. *Schloenbachia* cf. *varians* (J. Sow.) at 719 ft. ...	20	0	722	0
[Upper Greensand, 28 ft.]	Hard greenish glauconitic sandy marl with a few small phosphatic nodules	4	0	—	
	Dark grey sandy glauconitic marl with numerous burrows filled with glauconitic sandy marl with *Hoplites* cf. *auritus* (J. Sow.)	1	0	—	
	Fine grained calcareous sandstone, with minute grains of glauconite and specks of mica. Matrix of bed crowded with sponge-spicules	23	0	750	0
[Gault, 249½ ft.]	Grey slightly micaceous clays, sandy at top, and sprinkled with grains of glauconite at base ...	23	0	—	
	Grey glauconitic clay with numerous large black and white skinned phosphatic nodules ...	0	6	—	
	Dark slightly micaceous clay with a few white skinned phosphatic nodules	44	6	818	0
	Dark clay, no cores	165	0	983	0
	Sandy clay, very gritty towards base. Water	16	6	999	6
[Lower Greensand, 131 ft.]	Fine sand	25	2½	—	
	Fine sand with coarse concretions	14	0	—	
	Medium sand	19	6½	—	
	Soft fine sand	19	9	1078	0
	Clayey band, not described ...	12	0	1090	0
	Very loose sand	40	6	1130	6

The cores down to the depth of about 300 ft. were not preserved, but from the details of the beds recorded in the log of the boring, it appears that the Upper Chalk consisted mainly of white chalk with numerous flints in the uppermost 200 ft. According to the log, red mottled clay belonging to the Reading Beds overlies the Chalk, as in Horlick's boring, at Slough (*see* p. 158), but the zonal position of the highest portion of the Cretaceous rocks was not determined. At

Slough Motor Transport Depôt, cont.

the base of the subdivision a hard whitish-grey chalk with a layer of bright green-coated nodules represents the Chalk Rock. Its thickness is estimated to be about 10 ft., but may be less.

The Middle Chalk was well displayed in a nearly complete sequence of cores, and consists principally of beds of white chalk with a few marly bands. The Melbourn Rock is characteristically developed at the base, and shows about 9 ft. of hard splintery chalk, thin bedded in places, with irregular surfaces streaked with greenish marl. Numerous fragments of *Inoceramus* and *Rhynchonella* were found, but these proved insufficient to determine the zonal subdivisions.

The top of the Lower Chalk is formed by a 6-in. band of laminated grey green-tinged marl containing numerous fish remains, and is regarded as representing the Belemnitella Marl. The Zone of *Holaster subglobosus* appeared to be about 95 ft. thick, consisting mainly of greyish-white chalk, hard in places, with some marly layers. Some of the hard bands occur on a horizon corresponding to that of the Totternhoe Stone, and may be feeble representatives of it. The Zone of *Schloenbachia varians* is represented by soft dark marly chalk, which becomes sandy in places. The beds are highly fossiliferous, containing in addition to the zonal fossil, *Schloenbachia coupei* (Brongn.) and numerous fine specimens of *Inoceramus crippsi* Mant. The zone reaches a thickness of about 97 ft.

The Upper Greensand is somewhat thicker than the equivalent rocks in Horlick's well at Slough. The top bed is a hard glauconitic sandy marl, which passes downwards through a thin bed of dark grey marl into the Hearthstone Series. These are represented by 23 ft. of fine grained calcareous sandstone with minute grains of glauconite and specks of mica, the matrix being crowded with sponge-spicules. The Hearthstones are not sharply differentiated from the clays of the underlying Gault at the junction of the two formations.

Owing to boring troubles, little of the Gault clay was available for examination. The upper part consists of grey clay with a 6-in. glauconitic band containing large black and white skinned phosphatic nodules. The base of the Gault is taken at a depth of 999 ft. from the surface.

The Lower Greensand seems to be represented by fine sands. At 1,078 ft. a band of clay, 12 ft. thick, was passed through, and this is probably comparable with the bed of clay entered in the Maidenhead borehole at 1,023 ft. from surface (*see* p. 348). Water appeared at about 987 ft., but overflowed copiously when the boring reached the depth of 999 ft., and the present yield is estimated at between 180,000 and 200,000 gallons an hour.

Analysis of the Water from the Lower Greensand, by Dr. J. C. Thresh and Dr. J. F. Beale.

Sample taken when the boring was 1,115 ft. deep, on June 29th, 1920, by W. H. Booth.

Physical Examination.

Turbidity. Dull, due to trace of oxycarbonate of iron in suspension. Colour, faint yellow. Odour, none. Reaction very faintly alkaline.

Chemical Analysis. In parts per 100,000.

		Probable combination—	
Ca	2·2	Ferro-oxycarbonate	·1
Mg	·35	Calcium-carbonate	5·5
Fe	·04	Magnesium-carbonate	1·2
Na	12·5	Sodium-carbonate	15·
CO_3	13·	Sodium-sulphate	6·3
SO_4	4·3	Sodium-chloride	8·9
Cl	5·4	Silica, &c.	1·4
NO_3	0		
		Total solid constituents, dried at 180° C. (given as 39·)	38·4

Hardness, temporary $6\frac{1}{2}°$, permanent $\frac{1}{2}°$, total 7°.

Free ammonia	·0660
Organic ammonia	·0008
Oxygen absorbed in 3 hours at 37° C.	·0040

Slough Motor Transport Depôt, cont.

Bacteriologic examination.

Number of organisms per cubic centimetre capable of growing upon nutrient gelatine at 20° C. in 3 days, 42.

Ditto, capable of growing upon agar at 37° C., 3.

Smallest quantity of water giving acid and gas in bile-salt glucose broth, 40 c.c.

Smallest quantity of water giving gas in bile-salt lactose broth, 50 c.c.

Smallest quantity of water containing the *Bacillus coli communis*, 50 c.c.

Smallest quantity of water giving the reaction of the *Bacillus enteritidis sporogenes*, 100 c.c.

Remarks

Bacteriologically the water is satisfactory, but it will be better when the works are completed, as it contains a few bacteria which certainly are not normal to water from such a depth.

Chemically it is an interesting water, since it belongs to the same class as the waters under London, derived from the Lower London Tertiaries. It is, however, better than these as it contains smaller proportions of common salt, and sodium-carbonate. The iron present may be normal in the water, or it may be due to the action of the water on iron pipes: it is very small in amount, and existing as carbonate, rapidly takes up oxygen when exposed to air and deposits as the insoluble oxycarbonate: the amount, however is so small that it is not likely to give trouble.

The hardness is very moderate, and the organic purity very high. It is an excellent water for domestic purposes, for boiler-use and for most manufacturing purposes.

It differs a little from the sample at 999 ft.; but we think that the sample at this depth contained a little subsoil-water. Mr. Booth says that this sample was taken soon after the Lower Greensand was touched, and would show contamination from the wash-water of the boring operations.

Being now in possession of the details of five deep borings in Buckinghamshire, or but just outside that county, it is of interest to compare the sections, to see their relations to one another, and to note any general conclusions that can be drawn.

In the following table the places are arranged from the west eastward, and the second, fourth and fifth, are practically in line, the other two being more to the north. The thicknesses of the various geologic formations are given in feet.

	Above Chalk.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.
Marlow	—	456	14	242	2½
Maidenhead	—	680	3½	256½	83
Wooburn (Upper Greensand not separated from Chalk) ...	17	511	—	246½	2½
Slough, Motor Transport ...	29	693	28	249½	131
Slough, Horlick's	78½	757½	19	166	—

The first thing to note is a fair agreement in the thickness of the Chalk, allowing for the facts that at Marlow only the very bottom part of the Upper Chalk is present, that at Maidenhead the very topmost part of that division is absent, and that at Wooburn the boring starts

in its lower part. Only at the two Slough borings do we get the full thickness. At Horlick's this is high, but perhaps there may be some small misreading of the section. At the Motor Transport Depot the thickness is some 64 ft. less, which would not have been expected within so short a distance.

The second point is the thickness of the Gault, which is remarkably even; but here again Slough (Horlick's) is the exception. This constancy of thickness is more emphasized on taking the Upper Greensand and the Gault together, that is to say, treating them merely as parts of one formation, the Selbornian, when we get the following figures :—256, 260, 246½, 277½, 185.

Thirdly, it will be seen that in three of the five cases the Lower Greensand has been pierced only to a trifling depth. In the case of Maidenhead it has been thought to have been proved to the base; but, as above noted, we are not sure that this is the case; the clay found at the bottom may belong to this formation. At the Motor Transport Depot a much greater thicknesss of Lower Greensand has been found, and without reaching the base (December, 1920).

Now for practical purposes, equally as for geologic interest, it is important to know the thickness of the formation with its composition from top to bottom, and one feels therefore that, where possible, borings should be continued until this knowledge has been given us.

It may be urged that small towns like Maidenhead and Marlow can hardly be expected to carry out costly work of this kind, for experimental purposes beyond their own needs, and this is certainly reasonable. Is there not however some means by which, when such work may fairly be looked on as finished, from the local and particular point of view, it may be carried on as of importance from a general one ? Many opportunities of this sort have been lost: surely it is time to prevent others from following.

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